Feasibility and Potential Assessment of Wind Resource a Case Study in North Shewa Zone, Amhara, Ethiopia

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Abstract

The assessment of wind resource potential and feasibility is critical for generating and forecasting power generation, as wellas resource identification. In Ethiopia, the majority of the country lacks a wind atlas, making it difficult to determine the availability of sources. Seven different areas (Debre Berhan, Alem Ketema, Mehal Meda, Eneware, Gundo Meskel, Majete and Shewa Robit) were investigated. For the work data was collected from various sources and analyzed using MATLAB software. The basic sources of data that were obtained nationally were from the NMA, which is the National

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Metrological Agency found in Addis Ababa, and were obtained centrally from each local delegate's registered report from a height of 2 meters and 10 meters in each listed districts above. According to the results analysis, the average wind speed at most sites is reasonable and 4 m/s at a height of 10 meters, and some of the case study sites have an average wind speed of less than 3 m/s. The extrapolation prediction method produces more realistic results at 30 and 50 meters; for example, when 10 meter is extrapolated to 30 and 50 meters, the wind power densities are 75.2 w/m^2, 300.9 w/m^2, and 680.5 w/m^2, respectively. Similarly, the average yearly energy density for 10 meter, 30 meter, and 50 meter is 2110.8, 4122.6, and 8219.9 Kwh/m^2/year, respectively. As per the international standard for wind power and wind speed classification, Eneware and Mehal Meda are categorized under class 7, whereas Debre Berhan is categorized under class 3, while the remaining sites such as Shewarobit, Gunde Meskel, Alem Ketema, and Majete are classified under class 1 for the majority of the year.

Keywords: Wind energy, feasibility assessment, power density, energy density and renewable energy.

1 Introduction

Ethiopia has abundant renewable energy resources; Ethiopian Electric Power (EEP) is authorized for power generation in the country. Hydropower is currently the country's primary source of electricity, with an exploitable potential of 45000 MW, while wind and geothermal energy have exploitable potentials of 10,000 and 5000 MW, respectively. Besides this, the country has an estimated 5.26 kWh/m^2 solar potential [1]. Even if the total exploitable renewable energy resources of the country are nearly 60,000 MW, with the current dominance of hydropower, which is 90%, the total available capacity is only 4250 MW. From this, the share of wind power generation is 8%, and the remaining 2% is shared by geothermal and diesel power plants. If ongoing projects such as the renaissance dam which is the country's largest hydropower plant, geothermal and wind projects are completed within the next two to three years, the country's total capacity will reach 10,000 MW [1, 2].

As the country's main energy generation source is hydro power and only the dams get filled during the rainy season, when the amount of rain fall decreases from November to May, the generation will be reduced step by step. A good solution for this is wind power, which will have a complementary nature to hydro power because during the dry season when water in the dam is reduced, the potential of wind is good and can supplement the power, whereas during the rainy season wind generation is reducing and this is compensated by hydro power.

Based on the previous completed wind power project experiences such as the 51 MW, 120 MW, and 153 MW of Adama I, Ashegoda, and Adama II wind farms, Ethiopian Electric Power (EEP) has currently completed the feasibility study of the Ayisha I and Ayisha II wind projects in the Somali region with each having a potential capacity of 120 MW. Currently, the construction is under way. A Comparison of Ethiopian Indigenous Energy Resources is presented in Table 1 [3]. As the country is located in an equatorial region, there are enough sun rays, which will be a good cause for wind potential resources, but even if there is good potential, most people are without electricity and use traditional biomass, which is obtained by deforestation, to cook food. This is another environmental pollution crisis that is against the carbon reduction policy of the world agreement. People living in rural areas use fossil fuel for lighting and cooking food in the North Shewa Zone. According to the preliminary survey of the North Shewa Zone of the Amhara region, almost 80% of the population living in both rural and suburban areas have no access to electricity. Due to this problem, schools, health centers, and agriculture for irrigation are unable to access grid electricity, which directly or indirectly affects the livelihood of the population. We observe such problems during data collection and site visits in each district and kebele.

The rural and suburban population of the North Shewa Zone settlement is such that the first settlement by the government consists of 100–150 households in one area, while the other settlements are indigenous family groups with 10–15 households. Recently, householders in each case have an average of five to six family members. Even if the area under study has tremendous resources of renewable energy, such as wind, solar, and other types of energy. However, these resource potentials are not well identified as part of a solution by the researchers. Following the potential assessment of wind energy in this study, one can easily address electricity to the people in each target group. The wind pressure on trees in the study area at North Shewa is quite enormous. Wind power depends on different factors such as density and the cube of wind speed [4]. Table 2 shows the wind power classification at a height of 30 m and 50 m.

1.1 Related Works

Even if some non-government organizations (NGO) install micro-wind turbines in some selected districts of North Shewa for a few farmers for lighting purposes, there is no published paper on the potential assessment of wind in the case study area. One of the previous studies in the Amhara region is given in [2].

Although the installed capacity of wind has recently increased and it is now second rank to hydroelectric power, there are a few factors such as icing, extreme wind speed, permafrost, sea ice, and others that are affecting globally the coverage of wind generation, but the authors concluded that these factors do not jeopardize the exploitation of wind resources or energy in northern Europe [5]. In [6] world wind installation capacity and the leading wind energy producers such as China, the USA, Germany, Spain etc. are mentioned, and the installed capacity of wind reaches 370 GW by 1014, which is increased by 40% from 2013 and this capacity is bigger than by 44.6 GW of the 2012 installed capacity. Different methods of wind forecasting were studied to reduce the problems in the grid, but the higher spatial resolution method is slightly recommended as a better solution for wind forecasting [7]. Energy management system by combining energy production using wind generator turbine, diesel generator unit, and natural gas, the result shows that with wind energy, the energy output is uncertain, whereas natural gas results in a decrease in energy cost [8]. The IPCC, which is the Intergovernmental Panel on Climate Change, issued a special report on the role of renewable energies such as wind energy, ocean energy, solar energy, hydropower, and geothermal energy for climate change mitigation [9].

Renewable energy is becoming more widely used around the world as a result of its contribution to reducing greenhouse gas emissions as part of the Paris Agreement to combat global warming, as well as its inclusion in international law [10, 11]. The various renewable energy potentials of Ethiopia and the existing and future planned policies to promote energy production were discussed in [12].

1.2 Research Gap

- Based on the data collection from NMA, different techniques are missing from the various previous works of the researchers. On the other hand, this work considers and incorporates the following issues:
- Various literatures did not make use of the proposed work's practical system implementation.

Table 1 Comparison on review

S.No	Applied	Merits	Demerits	Reference
1	Weibull distribution	Considering at 50m height estimating the forecasting wind potential by using Weibull distribution.	Less comparison i.e. at different heights.	[13]
		Analysis wind speed using a wind map.	Data collection is better than two different resource for comparison	
2	Weibull model	Result comparisons were nice which includes different heights.	Sample data used for analysis was small, which is difficult for forecasting the wind potential	[14]
		Result analysis considering wind class, and the comparison between these nice	☐	
3	Weibull and	The analysis was used two techniques.	Only two years data were used for analysis.	[15]
	Rayleigh distribution functions	The analysis considered daily, annually, monthly, and seasonal variations of wind speed.	The wind potential comparison was not done at different heights.	
4	Weibull distribution	Considered different sites and better comparison.	Only considered wind mean which is difficult furcating the speed for the future	[16]
		Consider two data source for analysis	Less comparison i.e. considered only one height	
5	Weibull distribution	The sample data used for analysis was nice which gives the approximated wind potential.	Used secondary data of WAsP which may not be good for wind potential prediction	[17]
6	Weibull and Raleigh distribution functions	High sample data used which is nice for prediction the future	Wind potential comparison at different height is not considered	[18]

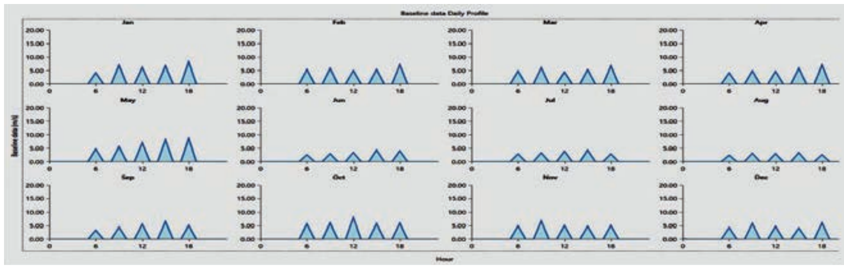

Figure 1 Wind data collection Eneware in 2019 sample.

- Different literatures didn't utilize the primary data for the analyzed of the adopted system, while this work utilized the primary data collected by measuring five times per day, which is practical data of the wind mean in North Shewa.
- Moreover, most researchers used data from older years and very small samples for data analysis, but for this work, the data collected and used are for 12 years and recent too, which is essential for forecasting future wind speed and potential.

1.3 Contributions of the Work

This work involves data collection, assessment, and simulation using different software of wind resources in the North Shewa Zone using MATLAB, HOMER, Wind Rose, and others. The resource assessment and analysis were used for predicting and planning the future power alternative for the zone for irrigation, commercial, domestic, industrial, and other loads. This work's major contributions are as follows:

- Assessment of wind resources in zone.
- Identification of the areas which have wind resources.
- Wind potential modeling, simulation, and output analysis based on the collected data.
- Wind resource potential assessment based on different heights and make a comparison.
- Wind power and energy density analysis at different heights and forecasting the future

2 Study Area Description

This research covers the areas of the North Shewa zone, which is found in the Amhara region of Ethiopia. North Shewa takes its name from the kingdom

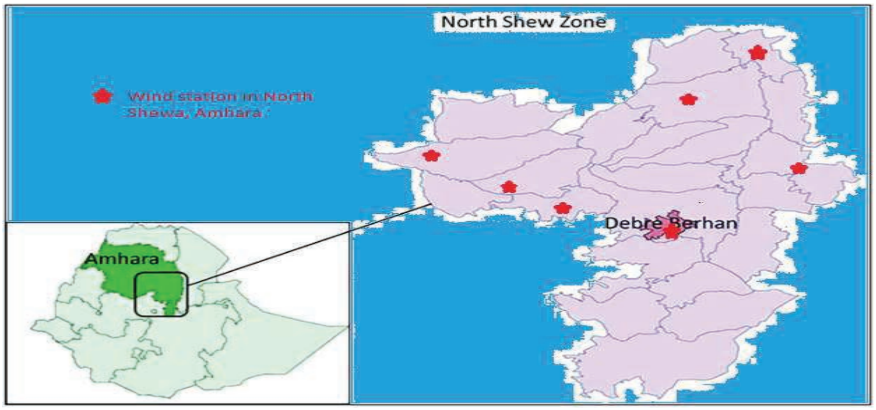

Figure 2 The map of North Shewa Administration zone.

of the former province of Shewa, Debre Berhan city, which is the main administrative center of the North Shewa. In this zone, there are 23 districts and 10 city administrations, such as Sela Dingay, Debre Berhan, Debre Sina, Shewa Robit, and Ankober. Based on the 2007 G.C census conducted by the Central Statistical Agency of Ethiopia (CSA), the zone has a total population of 1,837,490, of whom 928,694 are men and 908,796 are women. With an area of 15,936.13 square kilometers, 11.66% are urban. Total 429,423 households are counted in this zone, which results in an average of 4.28 people per household and 413,235 housing units [19].

Out of 23 districts in the North Shewa zone, only seven districts have meteorology centers. In this paper, the data is collected from the seven meteorology centers and online data from NASA. The Figure 2 shows the map of North Shewa, which has a meteorology center. This paper addresses seven of the total districts and city administrations in North Shewa such as Debre Berhan, Mehal Meda, Eneware, Gunde Meskel, Majete, Alem Ketema, and Shewa Robit.

3 Methodology

The data collected from meteorology centre of each location, which have shown in Figure 2 and at NASA. Based on the assessment data the analysis of the wind speed data, average wind parameters and standard deviation for more than ten years (2000–2019) by determining the parameters of the distribution functions. The analyzes wind energy evaluation and finds the wind speed extrapolation, wind power density, and energy density for three heights (10 m, 30 m, and 50 m).

3.1 Frequency Distribution of Wind Speed

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{k}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (\mathrm{k} > 0, \mathrm{v} > 0, \mathrm{c} > 1) \quad (1)$$

The corresponding cumulative probability function of the Weibull distribution is given by [20].

$$\mathrm{F(v)} = 1 - exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (2)$$

Where f(v) is the probability of observing wind speed; v and k are the dimensionless Weibull shape parameter, c is the Weibull scale parameter with a unit equal to the wind speed unit and F(v) is the cumulative probability function.

$$\mathrm{k} = \left(\frac{\sigma}{v}\right)^{-1.086} \quad (3)$$

$$\mathrm{c} = \frac{v_m}{1.253} \quad (4)$$

Where *Vm* is the mean value and σ is the standard deviation

$$v_m = \left(\frac{1}{n}\sum_{i=1}^{n} v_i^3\right)^{\frac{1}{3}} \quad (5)$$

$$\sigma = \sqrt{\sum_{i=1}^{n} \frac{(v_i - v_m)^2}{n}} \quad (6)$$

3.2 Wind Speed Variation with Height

$$v_2 = v_1\left(\frac{h_2}{h_1}\right)^{\alpha} \quad (7)$$

Where v_1 is the actual wind speed recorded at height h_1 (m) in (m/s) and v_2 is the wind speed at the required or extrapolated height h_2 (m) in (m/s). The exponent α depends on the surface roughness and atmospheric stability. Numerically, it lies in the range from 0.05–0.5.

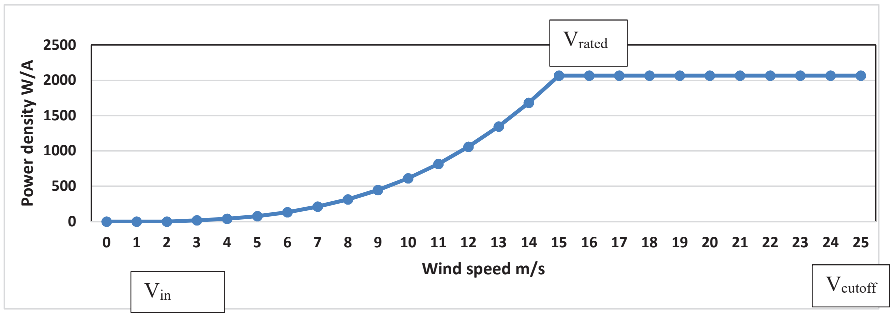

Figure 3 The power density function.

3.3 Wind Power Density Function

The power of wind depending on the speed of wind (m/s) and the sweep area of the blead (A m^2) [21].

$$P(w) = \frac{\rho A V^3}{2} \tag{8}$$

$$P_A = \frac{P(w)}{A} = \frac{\rho V^3}{2} \tag{9}$$

Where ρ kg/m^3 is the mean air density with value of 1.225 kg/m^3.

From the above Equations (8) and (9), the output power varies depending on the speed of wind. The power generated linearly up to 15 m/s and constant power can be generated until cut-off region (wind speed reaches 25 m/s). The rated wind speed (7 m/s to 15 m/s) is best for power generation. The Figure 3 shows the wind power generation at different wind speed, the output power increase linearly from 4 m/s to 15 m/s and constant at cut off region.

3.4 Wind Energy Density Function

$$E = P(w) * T = \frac{\rho A V^3}{2} * T \tag{10}$$

$$E_A = P_A * T \tag{11}$$

Where T is the time of the year, E energy Wh and E_A is energy per area.

4 Data Collection

In this paper, wind speed data collected at seven locations from NMA center and NASA at different heights. The seven locations investigated in this paper are Debre Berhan (9.633333, 39.5, 2750 m), Alem Ketema (10.033333, and 39.033333, 2280 m), Mehal Meda (10.3146, 39.66025, 3084 m), Eneware (9.83, 39.15, 2561 m), Gunde Meskel (10.1833, 38.71667, 2480 m), Majete (10.5, 39.85, 2000 m) and Shewa Robit (10.0127, 39.89436, 1277 m) with respect to latitude, longitude and altitude. This data has never previously been published and is also relatively recent, from the years 2000–2019 for 19 years data, taken at a height of 2 m and 10 m and measured five times daily, at 6:00, 9:00, 12:00, 15:00, and 18:00 for consecutive years. The data can be claimed to be complete for the given period with only a few recordings missing here and there. The missing data has been replaced by the averages of the preceding and following readings. This procedure was necessary to calculate the average monthly values.

4.1 Wind Potential Assessment at 2 meter (m)

The average wind speed of north Shewa zone is shown Figure 4, the data measured at 2 m height from national data center (NMA) at seven weredas. Hence, Eneware, Debre Berhan and Mehal Meda the wind speed at 2 m height is greater than 2 m/s, other sites Alem Ketema, Majete, Shewa Robit and Gunde Meskel the minim and maximum wind speed is 0.75 m/s and 1.75 m/s respectively.

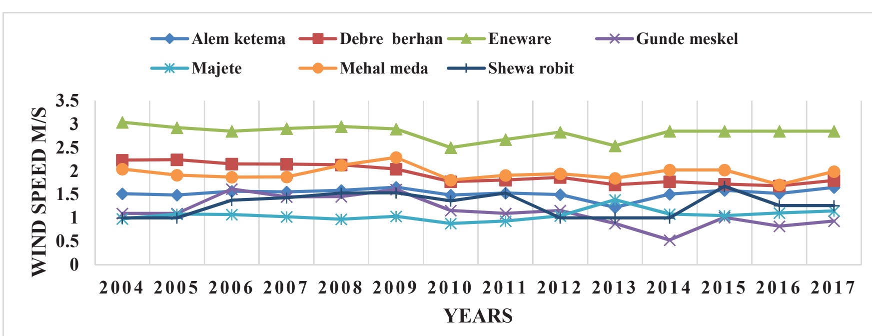

Figure 4 wind potential assessment of North Shewa at 2 m.

4.2 Wind Potential Assessment at 10 m

The Figure 5 shows the average wind speed of six sites at 10 meter height. From those sites Mehal Meda, Eneware and Debre Berhan have best wind speed and Alem Ketema and Gunde Meskel have moderate wind speed where as Majete have a poor wind speed.

The Figures 6, 7, and 8, shows the averages wind speeds of seven years (2013–2019) for Mehal Meda, Eneware and Debre Berhan respectively. It can be seen that the wind speed fluctuations are very high in the mid part of both years (the data were collected from September 2013 to August 2019). Hour 0 in both figures represents 12:00 of the respective day, where the maximum speed increases to 7.5 m/s, while the minimum speed is around 1.75 m/s at 10 m height in Mehal Meda. The wind speed is comparatively steady at the end and start of the year. The minimum and maximum wind speeds range between 1.5 and 8 m/s for the duration of between years at Eneware. Consequently, the mean wind speed ranged from 2 to 7 m/s for most of the time in between years in Debre Berhan. The wind speeds of 2013–2019

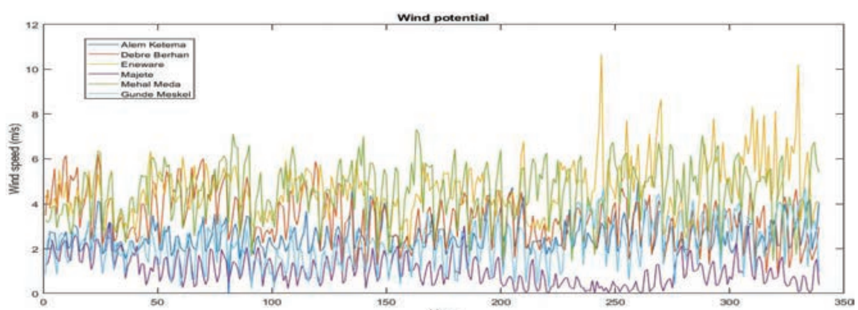

Figure 5 Wind mean of all sites at 10 m.

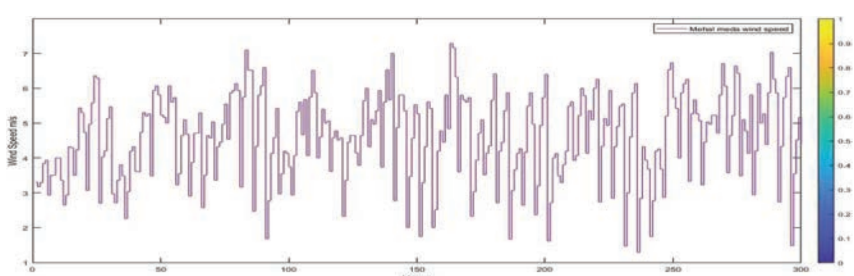

Figure 6 Wind mean of Mehal Meda at 10 m.

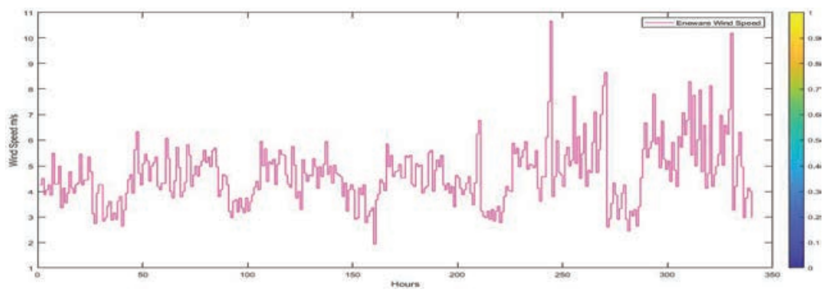

Figure 7 Wind speed of Eneware at 10 m.

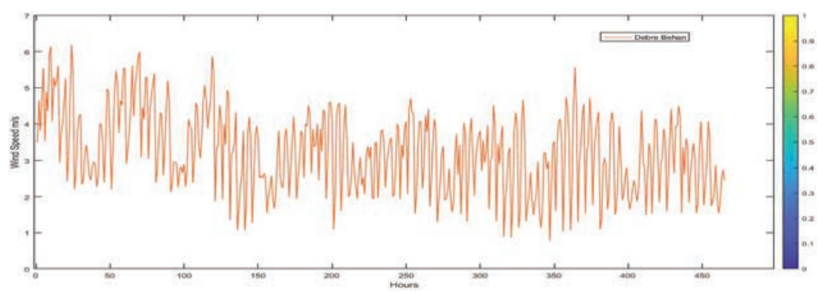

Figure 8 Wind speed of Debre Berhan at 10 m.

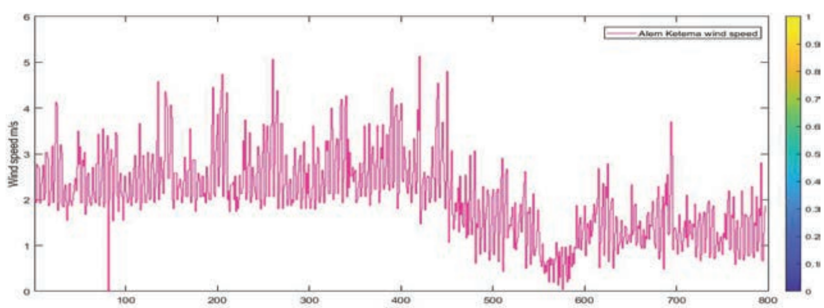

Figure 9 Wind speed analysis of Alem Ketema by Matlab at 10 m.

follow the same pattern, impartially decreasing the maximum occurrence of wind speed to a maximum value of 10.5 m/s.

The Figures 9, 10, and 11 the averages wind speeds for seven years (2013–2019) of Alem Ketema, Majete and Gunde Meskel respectively. These sites have low wind speed available at 10 m height with wind speed is between 0 to 5 m/s in Alem Ketema, 0.5 to 3.5 m/s in Majete and 0.25 m/s to 4.75 m/s minimum and maximum respectively.

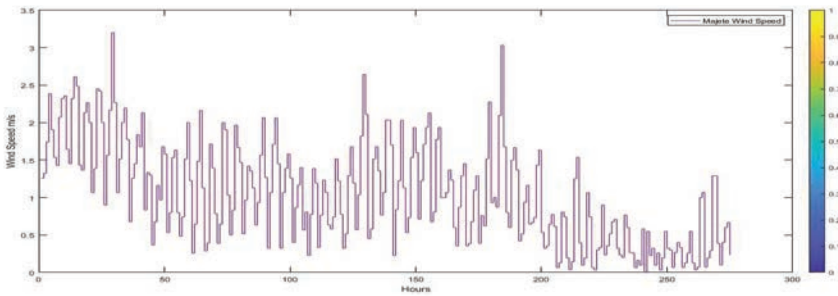

Figure 10 Wind speed analysis of Majete by Matlab at 10 m.

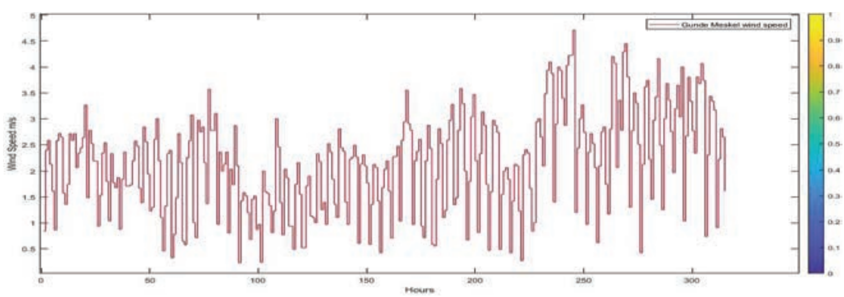

Figure 11 Wind speed analysis of Gunde Meskel by Matlab at 10 m.

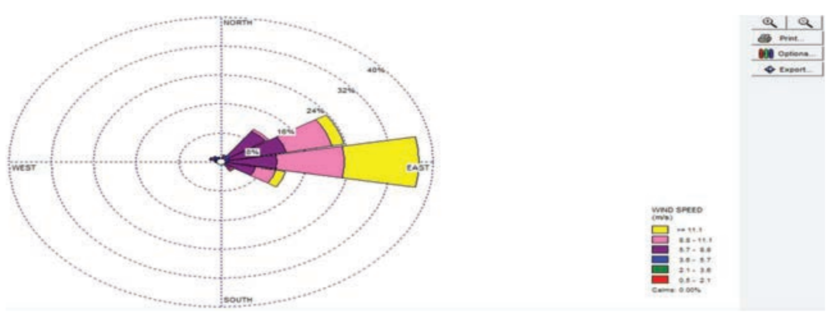

Figure 12 Wind direction (wind from) of the Eneware.

4.3 Wind Rose Analysis of Selected Sites

To determine the maximum output, an optimum configuration for the wind farm is required, so that the wind direction plays an integral part in obtaining this optimization. Figures 12 and 13 shows the average annual wind rose diagrams of two years at Eneware and Debre Berhan respectively. It can be

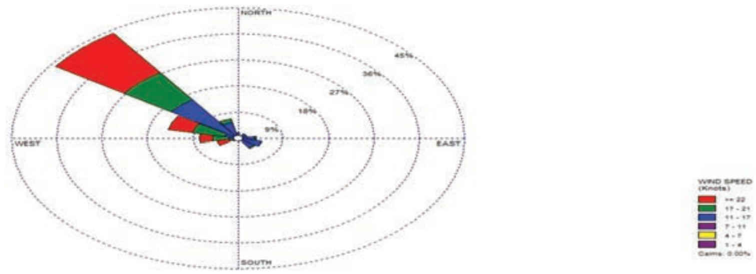

Figure 13 Wind speed and direction of Debre Berhan.

seen from the wind rose figure below that more than 40% of the wind is directed between 175 and 240 degrees clockwise.

Table 2 shows NMA data assessment and the results of monthly average wind speed at six sites. Even if the data collected more than 10 years, the table shows only 5 years. The result shows in north Shewa monthly average wind speed, most of the areas high wind speed occurred on October, November, December, and low wind speed measured in July, August, and September. The minimum and maximum wind speeds are 1.15 m/s at September and 1.9 m/s at November, 2.4 m/s at August and 5.3 m/s at December, 3.7 m/s at July and 6.98 m/s at May, 1.66 m/s at December and 3.16 m/s at March, 0.25 m/s at January and 0.76 m/s at March, 3.33 m/s at November and 5.85 m/s at May of Alem Ketema, Debre Berhan, Eneware, Gunde Meskel, Majete and Mehal Meda respectively.

After data collecting from NMA of Ethiopia, the paper analysis the wind speed at different heights as shown Figure 15. Most of the sites have the best wind speed above 30 m heights, which indicates the zone have wind potential. The wind speed changes with altitude, and the actual wind turbines are placed at different lengths, more than 10 meters from the earth's surface. In addition, to choose the appropriate height for the wind turbines, the average monthly and annual wind speeds are calculated at different heights 30 m and 50 m. This is the first step to using this data to calculate and evaluate wind power within the specified location. At these heights, the annual average of wind speed became 2.5 m/s at 10 m, 5.5 m/s at 30 m, and 8.5 m/s at 50 m, respectively, as shown in Figure 15.

The wind power density and energy for over 6 years at North Shewa zone including 7 weredas are presented in Figures 16 and 17, while the monthly wind power availability results not included in this paper since the work covers seven weredas so it is difficult to show here. The highest value of wind power density observed at Eneware wereda with maximum value of

Table 2 Wind speed assessment of North Shewa

Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2015	1.9448	1.4875	1.9241	1.6125	1.3290	1.3250	1.4188	1.3871	1.9907	1.5935	1.4313	1.4313
	2016	1.3600	1.5933	1.6256	1.4516	1.9313	2.3742	1.4000	1.4250	1.4645	1.7313	1.7355	1.5000
	2017	1.9448	1.4875	1.9241	1.6125	1.6968	1.9063	1.8839	1.5750	1.6750	1.6581	1.4938	1.5125
	2018	1.3250	1.3484	1.6250	1.4774	1.1500	1.2317	1.6367	1.8278	1.6141	1.1875	1.4875	1.9241
Alem Ketema	2019	1.4108	1.3239	1.4772	1.5478	1.5444	1.3804	1.6250	1.4774	1.1500	1.6968	1.9063	1.8839
	2015	2.9063	3.2261	3.9194	3.0581	3.5329	3.2120	2.5813	2.3313	2.7806	3.3125	3.2258	3.4688
	2016	3.2073	3.2067	3.0375	2.4000	3.0125	3.1226	2.1000	2.1750	2.5897	2.7938	3.6129	3.6149
	2017	3.1201	3.2101	2.8750	3.0014	2.0500	3.0146	2.7541	2.0160	3.1040	3.2140	3.5850	3.5230
	2018	3.6452	3.2250	3.3310	3.4375	2.2968	3.2438	2.6387	2.4125	2.2563	3.1290	2.9313	3.3871
Debre Berhan	2019	3.3787	3.2662	3.4798	3.1432	3.0433	3.2236	2.5066	2.3891	2.6631	3.0250	4.2387	5.2688
	2015	4.2563	4.6276	4.7313	4.9677	4.5688	4.0581	3.7313	3.0250	4.2387	5.2688	5.0645	5.0909
	2016	4.3438	4.9333	4.5563	4.1355	4.2188	4.9806	3.1938	3.2625	4.0129	5.6125	5.4839	4.8000
	2017	6.5097	5.0645	5.0909	4.7313	4.9677	4.5688	4.0581	3.7313	3.0250	4.2387	3.4375	2.2968
	2018	5.3063	4.7063	5.6828	5.4938	5.3097	6.7688	3.5355	3.5750	3.0875	5.2387	6.3871	5.5806
Eneware	2019	6.6250	6.2759	5.5813	5.2194	6.9813	4.8645	3.6688	5.3063	4.7063	5.6828	5.4938	5.3097
	2015	1.2625	1.6414	1.8438	2.0839	2.1313	1.9161	1.6813	1.7875	1.9806	3.1688	2.1097	2.0750
	2016	1.7375	2.2733	2.6375	2.2903	2.2625	2.2516	1.7563	1.6625	2.0258	2.3313	1.7875	1.9806
	2017	1.6000	2.1000	2.1200	2.4000	2.2000	2.0000	1.2000	1.7000	2.6000	1.8000	2.3000	2.0258
	2018	3.4813	3.1548	4.0442	2.6387	2.2750	2.1938	3.0581	3.9313	2.9419	2.7250	1.7875	1.9806
Gunde meskel	2019	2.8375	2.7793	3.1625	2.7613	3.5714	2.7032	2.1938	2.2903	2.2625	2.2516	1.7563	1.6625
	2015	1.0000	1.6483	1.1750	1.6000	1.2125	1.4194	1.7125	1.4500	1.3097	1.1500	1.7875	1.9806
	2016	0.7750	1.2467	1.7750	1.2774	0.8688	1.1613	0.7438	1.1313	0.9517	1.2500	1.3742	1.4452
	2017	1.1000	0.9000	1.1000	1.1000	1.2000	1.1000	1.6000	0.7000	1.3000	0.7000	1.3000	1.7000
	2018	0.4063	0.7172	0.5125	0.4774	0.6563	0.5935	0.4438	0.4813	0.5750	0.6194	1.7875	1.9806
Majete	2019	0.2500	0.5034	0.7625	0.5161	0.4063	0.7172	0.5125	0.4063	0.7172	0.5125	0.4774	0.4063
	2015	3.7938	4.7448	5.0688	5.6516	4.9250	4.2258	4.1688	3.7250	6.4000	5.4645	1.7875	1.9806
	2016	3.7313	4.7200	4.4688	3.3806	4.6375	4.5742	3.3063	3.7938	4.7448	4.1938	3.9931	3.4938
	2017	2.4000	1.8000	2.2000	2.9000	2.3000	2.1000	1.4000	1.7000	1.6000	2.1000	5.5290	5.6750
	2018	4.3688	4.8966	5.2938	4.5935	4.6313	4.2710	3.3313	3.4750	5.5290	5.6750	5.1161	4.8125
Mehal meda	2019	5.5563	5.1862	4.6063	4.6839	5.8563	5.1742	3.9188	4.5935	4.6313	4.2710	3.3313	3.4750

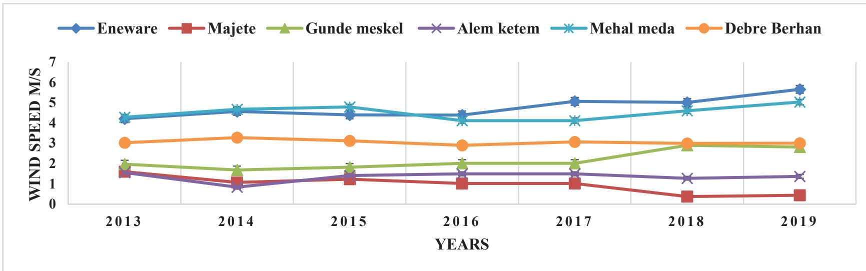

Figure 14 Annual wind mean of North Shewa at 10 m.

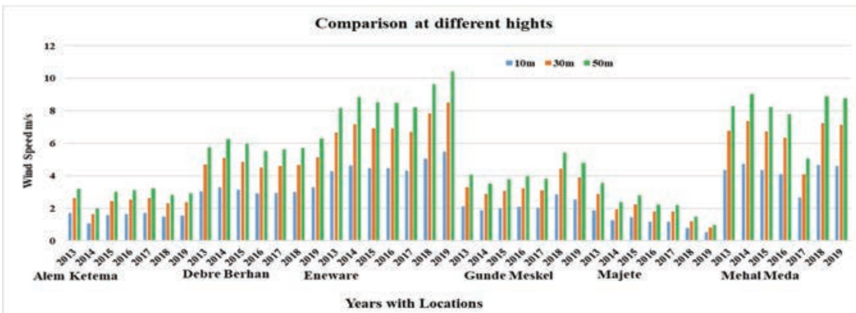

Figure 15 Wind speed Extrapolation at different height.

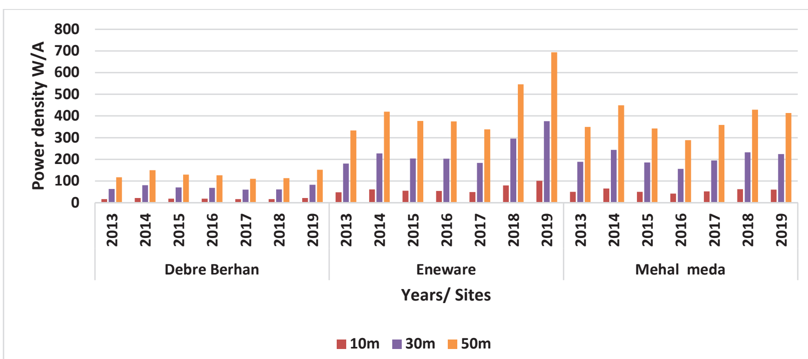

Figure 16 Best Wind Power density assessment and comparison.

689 W/m^2 at 50 m height, 390 W/m^2 at 30 m height in 2019 and the minimum power density value at Eneware 340 W/m^2 at 50 m height in 2013.

The annual energy density in this zone for over 6 years is shown in Figures 18 and 19. The maximum wind energy values occurred at Eneware

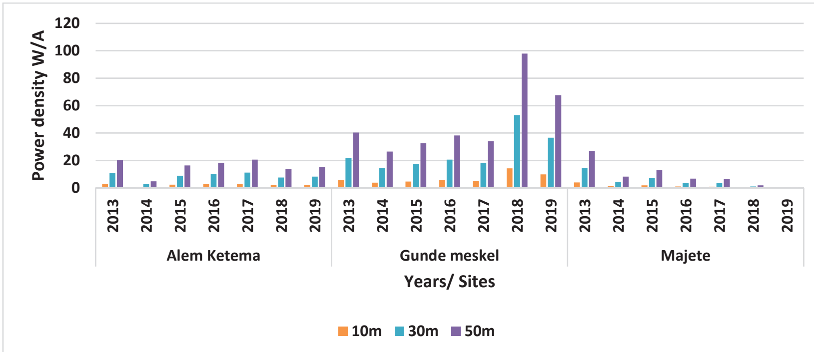

Figure 17 Low Wind Power density assessment and comparison.

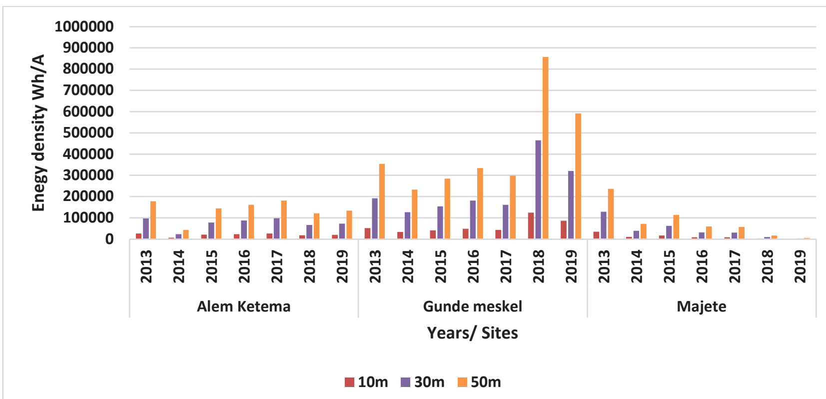

Figure 18 Low Wind Energy assessment of three locations.

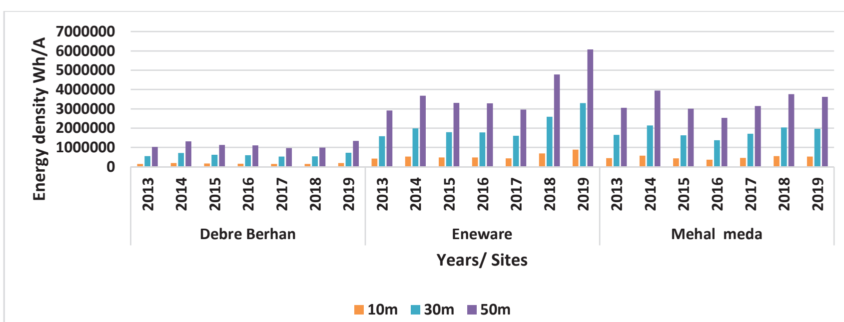

Figure 19 Best Wind Energy density of three locations.

and minimum Majete with the energy ranging between 113.7315 to 6078.914 kWh/m^2/year and the average monthly wind power availability in this zone was 100 W/m^2.

The wind speed classification of North Shewa is based on Table 2 Mehal Meda and Eneware at 50 m the wind speed is minimum 8 m/s which class 7 ‘superb’, Debre Berhan lies on class 3 and is classified as ‘Moderate’ with a minimum wind speed of 5.6 m/s. In these three weredas, the best wind speed at different heights, which means that the sites are considered suitable for electric wind on a large scale. The remaining weredas Majete, Gunde Meskel, Alem Ketema and Shewa Robit categorized under class 1 ‘poor’ with a minimum wind speed of 3.5 m/s at 50 m height. It has an average wind power density of 173.5 W/m^2, which means that the site is not good for wind power generation in large scale.

4.4 Wind Turbine Power Characteristics

The wind speed is essential for a wind turbine that can convert the wind energy into electricity. The electricity produced by the wind turbine has been calculated on a monthly basis employing the data from the power curve and the relevant frequencies of the wind speed. The wind turbine’s power curve, which gives the electrical power output as a function of wind speed, must be known. Figures 20, 21, and 22 show the wind turbine characteristics of Debre Berhan, Eneware, and Mehal Meda respectively, obtained from various values of the wind speed. Here it can be observed that the maximum power (active) is achieved through optimal wind speeds and not at high wind velocity. The wind turbine does not operate when the wind speed is less than the minimum speed because the captured wind energy is not enough to compensate the losses and operation cost.

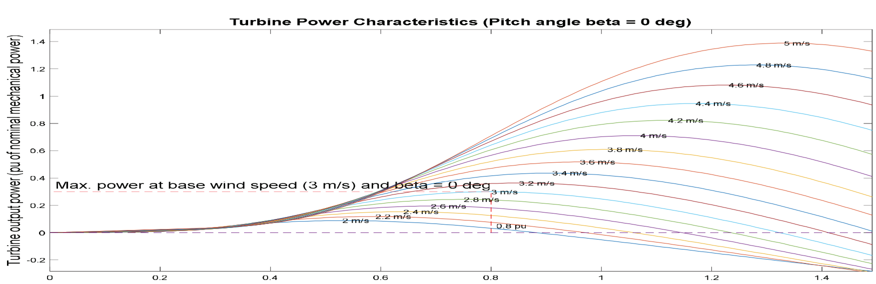

Figure 20 Wind turbine power characteristics of Debre Berhan at 3 m/s.

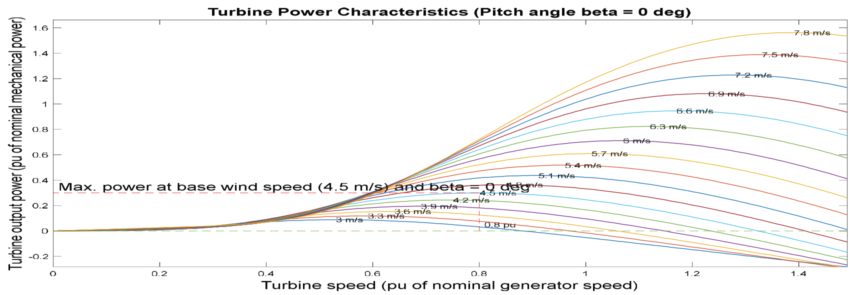

Figure 21 Wind turbine power characteristics of Eneware at 4.5 m/s.

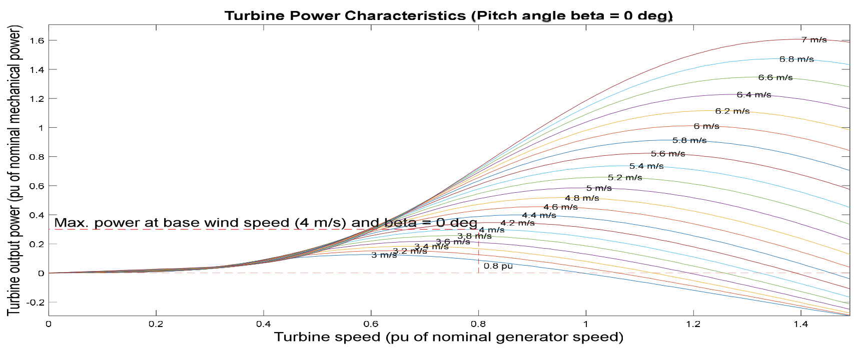

Figure 22 Wind turbine power characteristics of Mehal Meda at 4 m/s.

5 Conclusion

The wind speed and direction assessment and forecast wind speed potential are key points for wind energy industry. In this paper address on feasibility and potential assessment of wind speed, power density and energy density of North Shewa administration zone at seven selected weredas. The analysis more than 13 years wind speed and wind direction measured in 5-hours intervals of daily and monthly wind mean data at 2 meter and 10 meter height from the National Metrological Agency of Ethiopia were assessed. It was discovered that its annual variation recorded for the speed is maximum from 3.5 m/s to 10.5 m/s while the minimum value of 1.5 m/s to 8.2 m/s in the seven weredas. In the zone best wind potential available at Eneware and Mehal Meda while low potential occurred in Majete, with average annual wind speed 8 m/s, 7.25 m/s, and 2.5 m/s respectively. The wind power density observed at Eneware wereda with maximum value of 689 W/m^2 at 50 m height, 390 W/m^2 at 30 m height in 2019 G.C and the minimum power density value at Eneware 340 W/m^2 at 50 m height. The maximum wind energy values occurred at Eneware and minimum Majete 6078.914 KWh/m^2/year and 113.7315 KWh/m^2/year respectively. Based on the assessment and analysis of this work, most of the areas have the best wind speed, which can generate energy with wind farms, but Majete and Shewa Robit have low wind speed, which can be used for small-scale wind power generation for irrigation and lighting purposes in rural and suburban areas.

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