Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 1, January -2017

Assessment of Technical Wind Power Potential in Myanmar

ThiThi Soe[1], K. Boopathi[2], J.Bastin[2], A G Rangaraj[2], S.Gomathinayagam[2]

[1]*Renewable Energy Research Department, Department of Research and Innovation, Myanmar*
[2]*Wind Resource Assessment Unit, National Institute of Wind Energy, India*

Abstract —*In this study, wind power potential at 100 m AGL (above ground level) in Myanmar was examined technically by utilizing MERRA_2 (Modern-Era Retrospective analysis for Research and Applications) reanalysis datasets, Geo-informatics data sets and maps. The results show that promising wind potential areas are in Ayeyarwaddy, Yagon, Tanintharyi, Mandalay, Magway, Sagaing Regions and Rakhine States, the highest wind power density is 261 W/m² and installable technical wind power potential is 153 GW approximately. Based on the analysis by using industry-standard software, Annual Energy Production of 4454.88 MWh/year may be obtained with capacity factor of 25%. Subsequently, wind power potential was determined in different hub heights at 50 m, 80 m and 120 m. The results can fulfill to facilitate the development of wind energy not only for utility-scale generation but also village power and other off-grid applications in Myanmar. Therefore, this article provides technical wind power potential estimation to perform future wind feasibility investigations in Myanmar.*

Keywords-*capacity utilization factor, energy production, MERRA_2 reanalysis data, Myanmar, wind power*

I. INTRODUCTION

Wind power potential assessment is an important approach for a country's energy perspectives as it can identify how much electricity can be generated from wind resource in the region. Generally, the wind energy potential of one given area is traditionally assessed using locally acquired wind measurements, and, in order to realistically represent the local wind climatology for wind energy assessment, a minimum continuous period of 1 year measurement needs to be performed. Nevertheless, lack of reliable measured wind data in several areas of the globe still hampers the development of new wind energy projects, particularly in developing countries such as Myanmar. In this context, reanalysis datasets were considered in preliminary wind resource study.

The traditional utilization of reanalysis data is as a historical record of wind speed patterns which can be employed to correlate with actual short- term wind speed measurements from meteorological masts. The reanalysis data can also reduce the costs and risks of wind farm development by providing a source of long-term meteorological data that is difficult or expensive to acquire through normal meteorological measurement campaigns. Moreover, the reanalysis data are gridded datasets that combine data obtained from global circulation models (GCM's) with measured data. In mapping the average wind resource over large areas, NCEP-R2 (National Centers for Environmental Prediction), ERA-Interim (European Center for Medium- Range Weather Forecasts reanalysis series), NCEP-CFSR (Climate Forecast System Reanalysis), NASA-MERRA (Modern-Era Retrospective analysis for Research and Applications) are currently freely and publicly available [1]. Among them, MERRA dataset was chosen for estimation of wind power potential in this study.

MERRA is a NASA (National Aeronautics and Space Administration) reanalysis product with coupled numerical modeling with large quantities of empirical data such as surface measurements and earth observation satellite data to generate a long term continuous dataset. The main advantage of MERRA data is the availability of long-term wind speed data on a global grid and the original MERRA wind is in the public domain to construct the wind power density dataset. Therefore, the MERRA dataset had been used in several studies to estimate the potential wind resource such as in UK [2] and also other countries [3-7]. "Reference [3] investigated a model for the Swedish wind power production based on MERRA reanalysis data and noted that MERRA dataset has a relatively high temporal and spatial resolution". "Reference [4] also used reanalysis data from the MERRA data product and computed wind power density for the assessment of the wind power resource over Europe". "Reference [5] compared three NWP-based wind resource assessment methods (MERRA, AnEn based on MERRA, and WIND Toolkit) across the United States". "Reference [6] used MERRA boundary layer flux data to construct wind profile at 50 m, 80 m, 100 m, 120 m turbine hub heights and estimated wind power density of each level by comparing with NREL (National Renewable Energy Laboratory) wind map. One thing was observed that MERRA could provide a more accurate dataset using the comprehensive suite of satellite based information for climate and atmospheric research". "Reference [7] applied MERRA data to obtain wind speed data at an unobserved location in Germany". "Reference [8] found that MERRA data provided a more robust assessment of the temporal characteristics (i.e. mean, median, availability, intermittency, etc.) of wind power than that used in other studies". In this study, MERRA_2 reanalysis dataset is used for technical wind energy potential assessment in Myanmar. It hopes to perform the starting point for future wind feasibility investigations in Myanmar.

Recently, several authors have explored the wind potential assessment all over the world [9-21]. In this article, wind energy potential is estimated technically by using input data such as gridded reanalysis weather data, terrain elevations, land cover and socioeconomic data. The results will present in color-coded maps by using GIS (Geographic Information Systems) analysis tools. The study prompts to support whether government needs to figure out certain policies and regulatory frameworks that are required when there is enough potential to utilize wind energy through technical wind potential in Myanmar.

II. METHODOLOGY

The methodology involved in the work has been shown in Fig.1. Based on MERRA_2 reanalysis datasets, wind parameter layer is calculated and theoretical potential map at 100 m hub height is generated. Subsequently, interactive maps are prepared by using ArcGIS software to capture, store, manipulate the required data and obtain a holistic view of the study. Annual energy production (AEP) and capacity utilization factor (CUF) are technically exploited in GIS map by using 2MW normalized Wind Turbine Generator (WTG) power curve and Weibull distribution (with assumption of k=2). In geographical potential approach, exclusion layers are clipped from the wind potential map for the estimation of installable areas. All detailed steps are described in the following subsection.

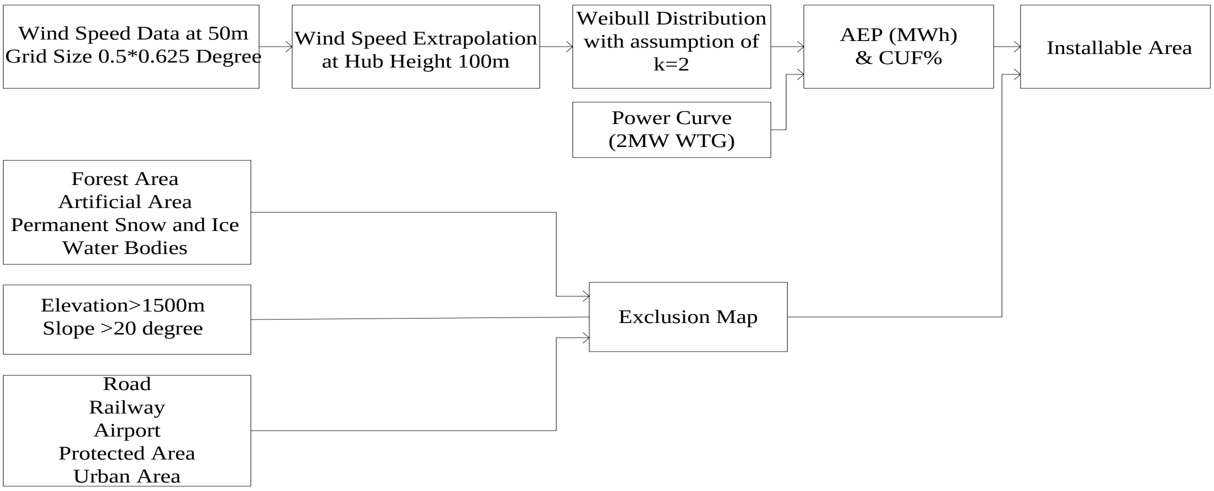

Figure 1.Overview Flow Chart of Methodology

2.1 Data sources

All necessary data of wind potential assessment were prepared by using GIS from publicly available databases. The wind speed data were collected from MERRA_2 reanalysis datasets for a period of 11 years (2005 - 2015) [22]. New version of the MERRA data set (MERRA_2) produced by the Global Modeling and Assimilation Office (GMAO) is available from the Goddard Earth Sciences Data and Information Services Center (GESDISC). The data is available on hourly basis over a grid spanning most of the globe at a resolution of 1/2 degree in latitude and 2/3degree in longitude and at a height of 50m above ground level (AGL). Mean wind speed at each point was used as input data to determine the wind speed variation across the study area. To exclude areas where development of wind facilities would be problematic, publicly available geographic information system (GIS) data on topography and land use were adopted. Land cover map was extracted from ESA Globcover 2009 (300 m) [23]. Shuttle Radar Topography Mission (SRTM) 3 arc-seconds data (about 90 m resolution) [24], was employed for exclusion of greater than 1500 m contour elevation and larger than 20-degree slope. Required socioeconomic map such as railways, roads and urban areas were collected from MIMU (Myanmar Information Management Unit) [25]. Protected areas (forest, national parks, and conservation areas) were identified to eliminate geographical areas which are not suitable for wind developments. The protected areas were applied from the World Database on Protected Areas (WDPA)[26] created by the United Nations Environment Programme, World Conservation Monitoring Centre, and the International Union of Conservation of Nature's World Commission of Protected Areas. The datasets were used for the estimation of wind potential in Myanmar and the corresponding sources were listed in Table 1 as shown below.

Table 1. Data Sources

No.	Data set	Source
1.	Wind Parameters	MERRA 2 (2005-2015)
2.	Land Use Land Cover Data Set	ESA Globcover 2009 (300m)
3.	Elevation and Slope information	SRTM (90 m)
4.	Road, Railway lines, Administration boundary, River details	MIMU (Myanmar Information Management Unit)
5.	Airports	Google Earth/ Online Sources
6.	Protected area	WDPA (World Database on Protected areas)

2.2 Wind speed adjustment

Since the MERRA dataset does not provide wind speeds at different hub heights, power law index method is used to extrapolate the available wind speeds to the turbine hub height. The basis equation of wind shear power law index method is,

$$\left(\frac{U}{U_r}\right) = \left(\frac{z}{z_r}\right)^{a} \quad (1)$$

in which, U is the required wind speed in m/s at required height (z) in meters. U_r is the reference wind speed in m/s at reference height (z_r) in meters. α is the dimensionless power law exponent also known as wind shear exponent. The following formula describes an empirical method that gives a correlation for the power law exponent as function of velocity and height.

$$\alpha = \left(\frac{0.37 - 0.088\,ln\,(U_r)}{1 - 0.088\,ln\left(\frac{z_r}{10}\right)}\right) (2)$$

in which, U_r is the reference wind speed given in m/s and z_r is the reference height in meters.

2.3 Wind power density

Wind power density (WPD) is a truer indication of a site's wind energy potential than wind speed alone. Its value combines the effect of a site's wind speed distribution and its dependence on air density and wind speed. WPD is identified as the wind power available per unit area swept by the turbine blades and is given by the following equation:

$$WPD = \frac{1}{2}\rho A U^3 (3)$$

in which, P is the power density given in W/m^2, ρ is the air density (kgm^{-3}) which depends on altitude, air pressure, and temperature, U is wind speed (m/s) and A is the rotor area (m^2). In this work, ρ is taken to be 1.225kgm^{-3}. The wind power density of the site can be expressed, again, by the following expression if only mean wind speed is known:

$$\frac{P}{A} = \frac{1}{2}\rho U^3 EPF (4)$$

Energy Pattern Factor (EPF) is the ratio of the actual mean wind power density to the wind power density calculated using only the mean wind speed. This can be estimated by using the already known reference values, with the most frequently adopted value being 1.5(widely applied to low surfaces and well exposed sites)[27].

2.4 Wind speed distribution

Wind speed distribution is essential for predicting the energy output of a wind energy conversion system. The wind speed probability density distributions and their functional forms represent the major aspects in wind. The probability distributions most commonly used are those of "Weibull" and "Rayleigh". The Weibull distribution has been found to fit a wide collection of recorded wind data. In this paper, the Weibull method is used, due to its greater flexibility and simplicity. The probability density function of the Weibull distribution is given below.

$$f(u) = \frac{k}{A}\left(\left(\frac{U}{A}\right)^{k-1} . \exp\left(-\frac{U}{A}\right)^{k}\right) (5)$$

in which, U is the wind speed, k is a shape parameter, and A is a scale parameter determined by the data. The scale parameter, A, indicates how windy a location is, while the shape parameter k, indicates how peaked the wind distribution is. For the present work, the scale is calculated as A=1.12 (U), shape parameter (k) is assumed as 2 and estimated Weibull distribution using Matlabprogramme.

2.5 Annual energy and capacity utilization factor

Calculation of annual energy output requires wind speed frequency distribution and the system power output of each turbine as a function of wind speed. The long-term wind speed distribution is combined with the power curve of the turbine to give the energy generated at each wind speed and hence the total energy generated throughout the year. This study used 2MW; normalized wind turbine generator (WTG). Bin width of wind speed is usually 1 m/s. The annual energy output is given by equation:

$$Energy = \sum_{1=1}^{i=n} P\,(Ui)\,H(Ui) (6)$$

in which, H(Ui) is the number of hours in wind speed bin Ui, and P(Ui) is the power output at that wind speed. Another measure is the capacity utilization factor (CUF) defined as the ratio of the actual energy generated in a time period to the energy produced if the wind turbine had run at its rated power over that period. The capacity utilization factor is therefore calculated as:

$$Capacity\ Utilization\ Factor_{Annual} = \left(\frac{energy\ \ generated\ \ per\ year\ (kWh)}{turbine\ \ rated\ \ power\ (kW) P_n 8760}\right) \times 100 (7)$$

Several researchers applied these above well established Equations (1-7) [11, 13, 21, 22] for their appropriate research cases. Similarly, these equations were also applied in the processing of wind power potential map in Myanmar.

III. RESULTS

To large-scale implementation of wind power in developing countries, the apparent intermittency of winds and the difficulty in identifying decent wind locations are two main barriers. As one of the developing countries, identification and defining the amount of wind power are therefore very essential to explore in Myanmar. Regarding this, the study provides the estimation of wind power potential in Myanmar technically to indicate possible and sufficient sites for future wind project implementation by demonstrating the results in GIS maps.

3.1. Wind speed and Wind power density map at 100m AGL

Using MERRA_2 reanalysis dataset, wind speed is reconstructed 50 m to 100 m hub height by Equation (1) and (2). Wind power density is calculated at 100 m height from Equation (3) and (4). The wind speed and wind power density maps are displayed and transformed into the grid format used by ArcGIS, TM ESRI (a firm Trademark specializing in geographic information software). The output color coded maps are described in Fig.2 and Fig.3 respectively.

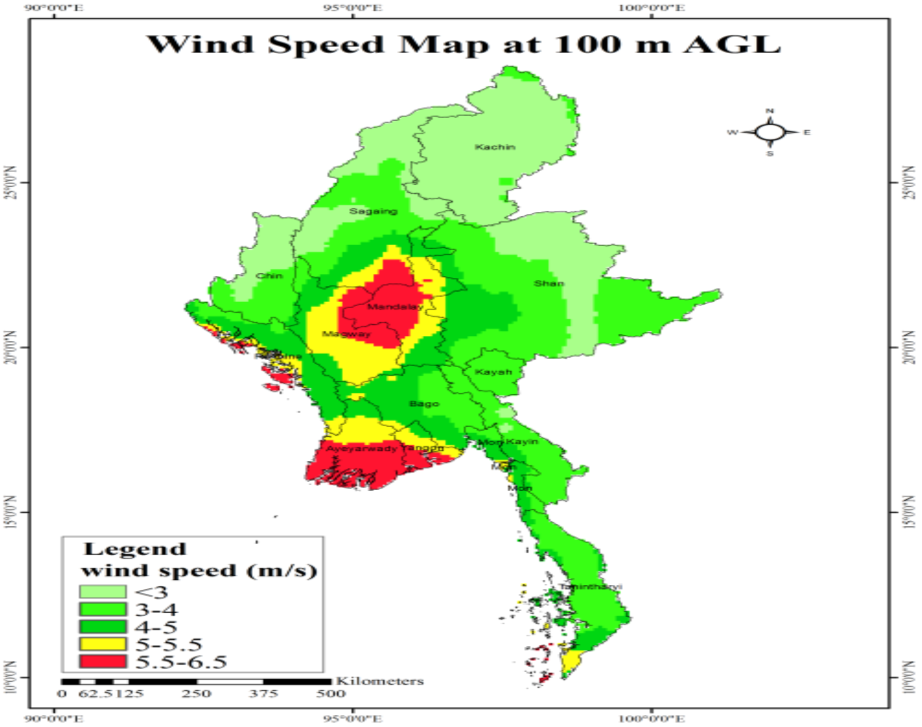

Figure 2. Wind Speed Map in Myanmar

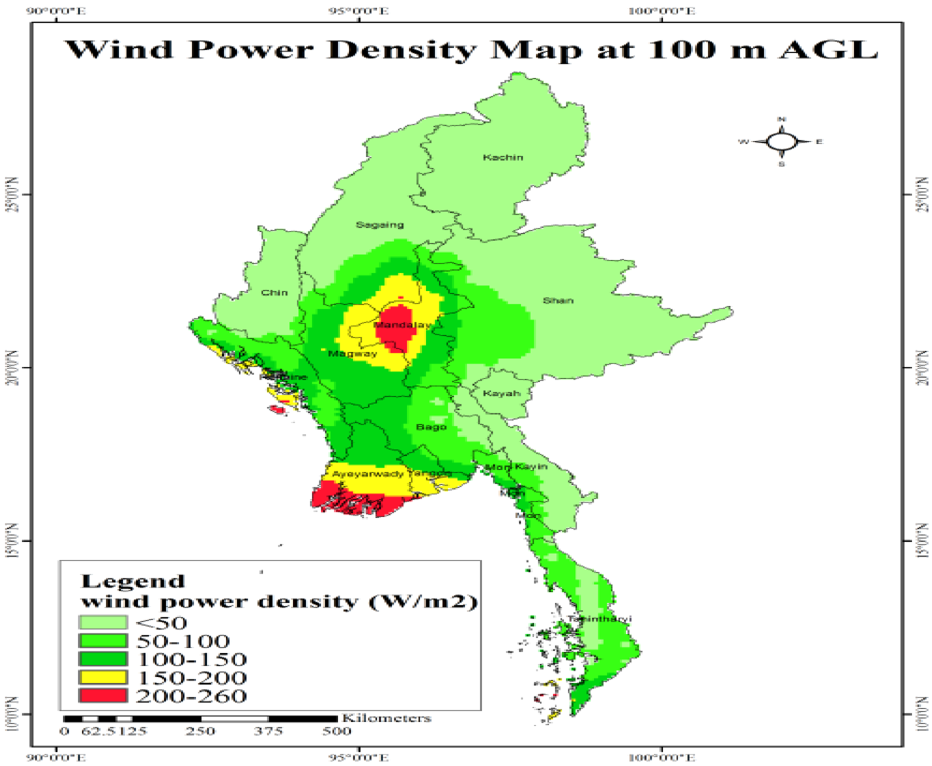

Figure 3.Wind Power Density Map in Myanmar

From the resultant maps, the highest wind speed regions are found in center of Myanmar and the coastal regions in the south and western parts of the country with 5-6.6 m/s of wind speed and wind power density of 200-261 W/m^2 captured with red color. The other displayed colors represent in each value of wind speed and wind power density respectively. The low wind speed (3-5 m/s) is widely spread in Myanmar. The higher wind penetration areas are in some part of Ayeyarwaddy, Yangon, Tanintharyi Regions and Rakhine States, which are in the coastal line of Myanmar and Mandalay, Magway and Sagaing Regions located in the central part of Myanmar with 200-261 W/m^2, WPD. According to this theoretical output result, these promising areas are potential areas for large scale wind power application as a source of sustainable energy and can be considered for future micrositing study.

3.2. Restriction map

After generating theoretical wind speed map and WPD map of Myanmar at 100m AGL, there is a need to exploit restriction map according to the topographical, political and technical point of views. As airport, railway, road, water bodies, protected areas, urban areas, forest areas, snow cover areas, land areas with elevation more than 1500 m and slope more than 20 degree are not suitable for land feature of wind farm siting, these restriction areas are set off appropriate buffer, converted into the vector layer and clipped off from the administration map. The assumption of buffer set are 5 km for airport location, 1 km for road, river and railway area, 5 km for city and 2 km for town area. The total restriction area is about 396817.56 km^2 noted 58% of total land area of Myanmar. The resultant map is shown in Fig.4

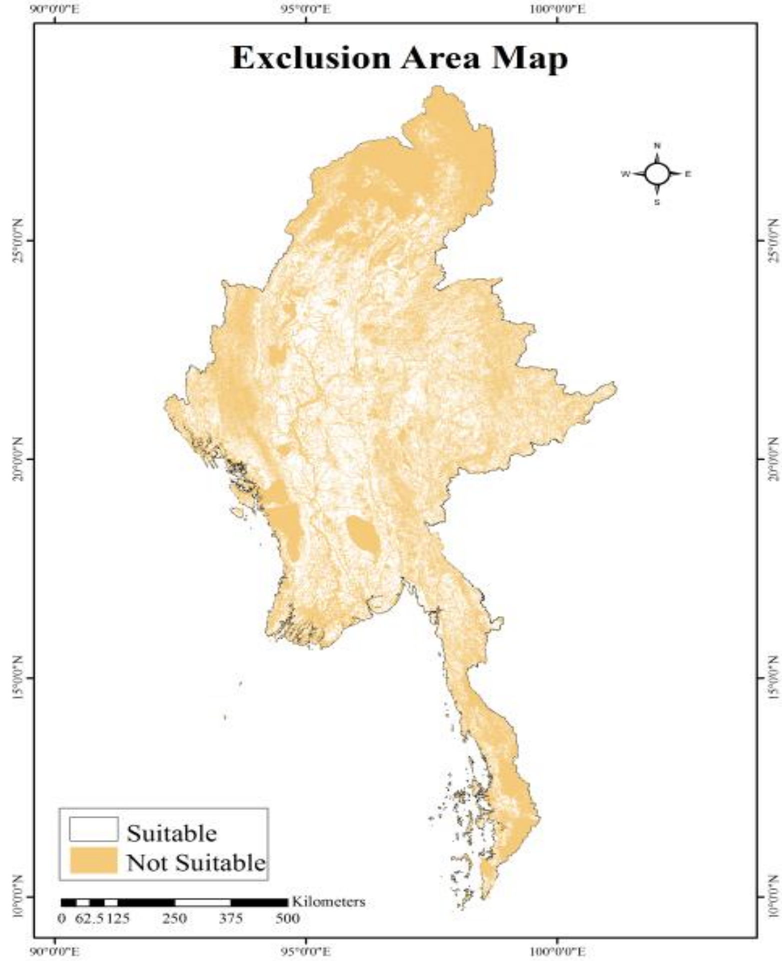

Figure4.Suitability Areas for Wind Power Installation in Myanmar

3.3. Estimation of annual energy production and capacity utilization factor

Following the attainment of the Weibull distribution parameters, the functions were applied to the power curve of 2MW wind turbine (normalized power curve) for estimation of annual energy production and capacity utilization factor. The annual energy production and capacity utilization factor were estimated by Equation (6) and (7). Technical wind potential map was assessed in 100 m hub height by extraction of restriction areas. In the rest of area, energy can be produced from 3591.24 MWh to 4454.88 MWh annually as shown in Fig.5 with the red color. Capacity utilization factor was exploited and defined with two different colors in Fig. 6. The green color areas are less than 20% CUF and the red one is displayed in more than 20% of CUF. Additionally, the country's national grid line is drawn in the map to consider the grid accessibility in future electricity generation source from wind power.

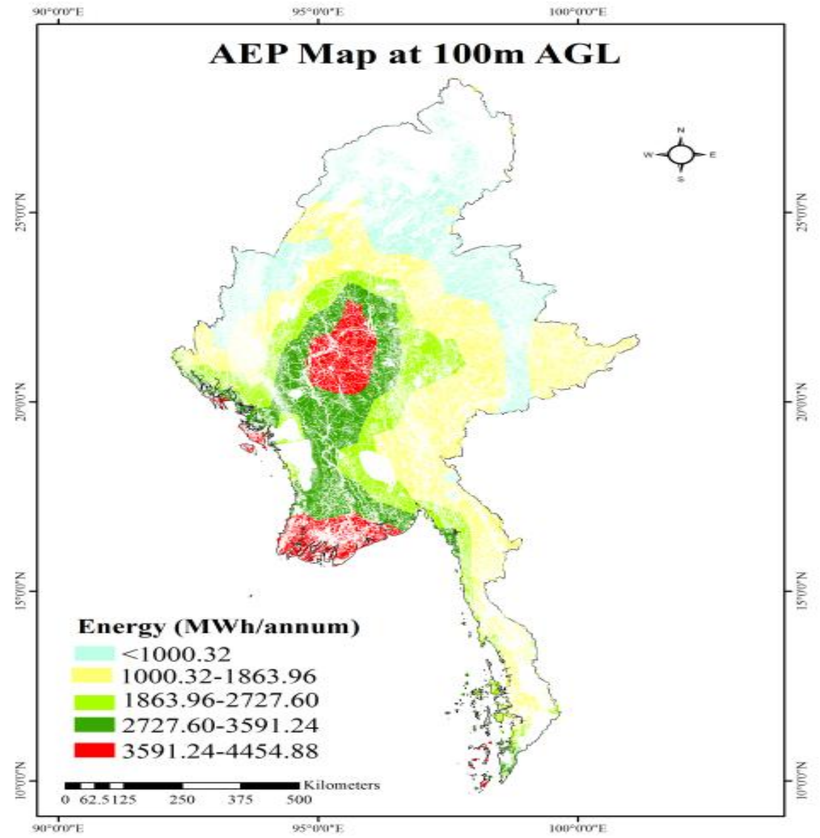

Figure 5.Annual Energy Production (AEP) Map in Myanmar

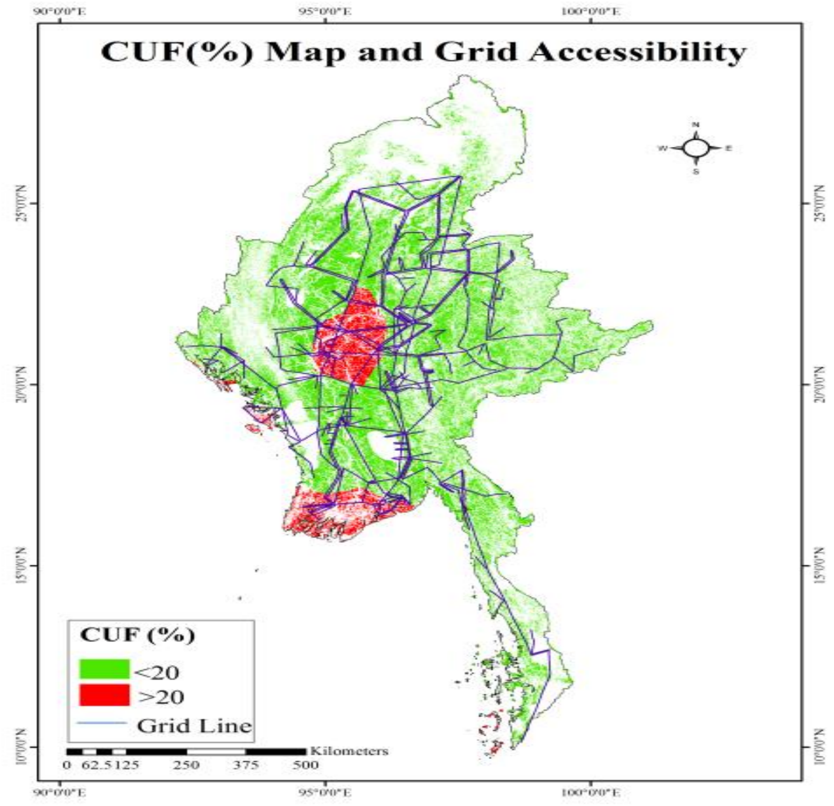

Figure6.CUF (%) Map and Grid Accessibility in Myanmar

3.4. Installable capacity

Referring to turbine spacing (5D ×7D), (D- the rotor diameter is 'm') a conservative assumption of 6 MW per sq-km is used in estimation of windy area and installable capacity in Myanmar. High quality wind energy sites are found in Ayeyarwaddy, Yagon, Mandalay, Magway, Saagaing, Tanintharyi Regions and Rakhine States with 20-25% of capacity factor and can install 152.762 GW at 100m hub height.

3.5. Wind Power Potential

Additionally, corresponding to wind turbine hub heights of 50 m, 80 m, 100 m and 120 m, generation with the same mapping procedure has been performed the results of wind speed, wind power density, annual energy production, capacity utilization factor and installable capacity were investigated. All these findings are shown in Table 2.

Table 2. Wind Power Potential in Myanmar at 50 m, 80 m, 100 m, 120 m AGL

Hub Height(m)	Wind Speed (m/s)	WPD (W/m^2)	AEP (MWh/annum)	CUF (%)	Installable Capacity (GW), CUF> 20%	P_{90}(GW)
50	0-5.5	0-153	0-3142.03	0-17	-	-
80	0-6.2	0-220	0-4018.39	0-23	70.696	41.53
100	0-6.6	0-261	0-4454.88	0-25	152.762	70.91
120	0-6.8	0-300	0-4816.24	0-28	238.850	110.87

According to the results, wind power potential in Myanmar can be favorable for not only for utility grid-connected but also rural power applications. Considering CUF greater than 20% in each level, the installable capacities are nearly 71 GW at 80 m hub height, 153 GW at 100 m hub height and 239 GW at 120 m hub height respectively. However, all these areas might not be installed in practically due to local constraints. Hence, the values should be dealt with caution. Therefore, probability of installable capacity (P_{90}) were observed in each hub height (80 m, 100 m, 120 m) considering with standard correction factors and uncertainly factors.This information is used to assess the project's bankability.Regarding these reference results at different hub heights in Myanmar, this research study is useful for governments, practitioners, and investors involved in the value chain of a wind farm investment.

V. DISCUSSION

For a long-term determination of wind speed and energy yield in Myanmar, the long-term MERRA_2 reanalysis data was used, with 11 years period and reconstructed the wind field at 100 m turbine hub heights to represent potentially much higher hub heights in the future. Regarding the resultant potential maps, the higher wind speed can be found in the central part and a long with the coastal area in the south and western parts of Myanmar. Therefore, the study results hope to fill the gap of missing standards of assessing the wind energy potential from a legal perspective and assist in creating a transparent approach for the valuation of wind production derivatives. To validate the output map, high quality land surface measurements data are not available yet in Myanmar. It is highly recommended to carry out on site measurement for verification of the result and confirmation of the wind resource at promising locations. However, this research outcome can cover validation of measurement results by seasonal and year-to-year wind variations in next phase of wind resource study in Myanmar. Moreover, the approach can be applied to other regions in the world since MERRA data are globally available. For further study, levelized cost of generation of electricity should be estimated for economic feasibility.

V. CONCLUSION

This study formed the starting point for future wind feasibility investigations and conducted to identify areas in Ayeyarwaddy, Yagon, Mandalay, Magway, Saagaing, Tanintharyi Regions and Rakhine States which require detailed assessments. In these respects, setting up met mast and measuring actual wind data can explore the high wind penetration regions for utilization of wind energy in Myanmar.

The mean wind speed, wind power density, annual energy production and capacity utilization factor were calculated in different hub heights (50 m, 80 m, 100 m, 120 m) based on 50 m MERRA_2 dataset for preliminary wind energy assessment. This information can be of interest to various stakeholders, investors, financiers, policy makers so that economic rationale of wind energy project can be examined in investing sector of Myanmar.

VI. ACKNOWLEDGEMENTS

The authors acknowledge the financial support for this work provided by the Centre for International Co-Operation in Science (CICS) and the India Science and Research Fellowship Program. The authors would like to thank Mary, who is a bright GIS engineer and helps the required expertise in Geo-informatics.

REFERENCES

[1] D. Carvalho, A. Rocha, M. Gómez-Gesteira , C. Silva Santos , "WRF wind simulation and wind energy production estimates forced by different reanalyses: Comparison with observed data for Portugal", Applied Energy 117 (2014) 116–126.

[2] The Crown Estate, "UK MERRA Validation with Offshore Meteorological Data", October 2014.

[3] Jon Olauson , Mikael Bergkvist, "Modelling the Swedish wind power production using MERRA reanalysis data", Renewable Energy 76 (2015) 717-725.

[4] Alexandra Cosseron, C. Adam Schlosser, U. BhaskarGunturu, "Characterization of the wind power resource in Europe and its intermittency Report No. 258, March 2014.

[5] Jie Zhang, Caroline Draxl, Thomas Hopson, Luca DelleMonache, Emilie Vanvyve, Bri-Mathias Hodge, "Comparison of numerical weather prediction based deterministic and probabilistic wind resource assessment methods", Applied Energy 156 (2015) 528–54.

[6] U. B. Gunturu and C. A. Schlosser, "Characterization of wind power resource in the United States", Atmospheric Chemistry and Physics, 12, 9687–9702.

[7] M. Ritter, Z. Shena, B. López Cabrera, M. Odening, L. Deckert, "A new approach to assess wind energy potential", The 7th International Conference on Applied Energy – ICAE2015, Energy Procedia 75 (2015),pp. 671 – 676.

[8] Willow Hallgren, UdayaBhaskarGunturu, Adam Schlosser, "The potential wind power resource in Australia: A new perspective", PLOS ONE, Volume 9, Issue 7, e99608, July 2014, www.plosone.org.

[9] Technical Paper Series (TP-01 -14), "World Wind Resource Assessment Report", World Wind Energy Association Technical Committee, December 2014.

[10] Olayinka S. Ohunakin, "Wind characteristics and wind energy potential assessment in Uyo, Nigeria", Journal of Engineering and Applied Sciences 6(2): 141-146, ISSN: 1816-949X.

[11] Dimitrios Mentis, "Wind energy assessment in Africa A GIS-based approach", Master of Science Thesis, KTH School of Industrial Engineering and Management, Energy Technology EGI-2013.

[12] European Environment Agency Technical Report, "Europe's onshore and offshore wind energy potential, An assessment of environment and economic constraints", ISSN 1725-2237, No (6/2009).

[13] Dimitrios Mentis, ShahidHussainSiyal, AlexandrosKorkovelos, Mark Howells, "A geospatial assessment of the techno-economic wind power potential in India using geographical restrictions", Renewable Energy 97 (2016) 77-88.

[14] AmolPhadke, RanjitBharvirkar, and JagmeetKhangura, "Reassessing wind potential estimates for India: Economic and policy implications", Ernest Orlando Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division, July 2011.

[15] Kaushik Sharma, M. Rafiuddin Ahmed, "Wind energy resource assessment for the Fiji Islands: Kadavu Island and Suva Peninsula", Renewable Energy 89 (2016) 168-180.

[16] B.R. Karthikeya, Prabal S. Negi, N. Srikanth, "Wind resource assessment for urban renewable energy application in Singapore",Renewable Energy 87 (2016) 403 – 414.

[17] David Watts, Nicolas Oses, Rodrigo Perez., "Assessment of wind energy potential in Chile: A project-based regional wind supply function approach", Renewable Energy 96 (2016) 738-755.

[18] Nikolai Nawri, GuðrúnNína Petersen, HalldórBjornsson, Andrea N. Hahmann, KristjánJónasson, Charlotte Bay Hasager, Niels-Erik Clausen, "The wind energy potential of Iceland", Renewable Energy 69 (2014) 290-299.

[19] KianaRahmani, Alibakhsh Kasaeian, Mahdi Fakoor, Amirreza Kosari, SayyedbenyaminAlavi, "Wind power assessment and site matching of wind turbines in Lootak of Zabol", International Journal of Renewable Energy Research, Vol.4, No.4, November 2014.

[20] Uquetan, U. I. Egor, A. O., Osang, J. E., Emeruwa, C, "Empirical study of wind energy potential in Calabar, Cross River State, Nigeria", International Journal of Scientific & Technology Research ISSN 2277-8616, Volume 4, Issue 10,October 2015.

[21] Y.K. Sanusi, S.G. Abisoye, "Estimation of wind energy potential in Southwestern Nigeria", The Pacific Journal of Science and Technology, Volume 12.Number 2. November 2011.

[22] http://earthdata.nasa.gov [accessed in 28.9.2016]

[23] http://due.esrin.esa.int/page_globcover.php [accessed in 17.10.2016]

[24] http://earthexplorer.usgs.gov [accessed in 25.10.2016]

[25] http://www.themimu.info/gis-resources-agency-maps [accessed in 31.10.2016]

[26] https://www.protectedplanet.net/country/MM [accessed in 11.11.2016]

[27] Siraj Ahmed, Wind Energy: Theory and Practice, Eastern Economy Edition, ISBN-978-81-203-4066-4, 2010, pp. 8-47.

