Assessment of Economic Feasibility on Promising Wind Energy Sites in Myanmar

Thi Thi Soe***, Maosheng Zheng**‡, Zar Ni Aung*

*Renewable Energy Department, Myanmar Scientific and Technological Research Department, Myanmar
**School of Chemical Engineering, Institute for Energy Transmission Technology and Application, Northwest University, Xi'an 710069, China

‡ Corresponding Author; Maosheng Zheng, e-mail: mszheng2@yahoo.com

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Abstract-This paper presents the selection of the best potential wind resource from preliminary wind atlas, and studies the economic feasibility analysis of these sites by matching with the wind data of each site and characteristics of low wind speed wind turbine. The selected sites are emerging from Arakan, Pathein, Yangon and Ye, which are likely to be facilitating areas from isolated-grid and other off-grid. Therefore, eight low wind speed wind turbines are selected from product data sheet of RETScreen and matched with wind data of each site for assessing the economic feasibility. The best wind turbine is Enrgie (PGE 20/25-25m) for each site to get the lowest price, the highest capacity factor, the maximum energy production and the greatest green house gas (GHG) emission reduction. To check the economic feasibility of this project, the parameter of net present value (NPV), internal rate of return (IRR) and simple payback period (SPB) are adjusted for verification of sustainable development. The sensitivity analysis is also performed for back up findings of project development. This research can investigate the potential and feasibility of developing small scale wind farm with isolated-grid for electricity generation at remote areas of Myanmar.

Keywords: Wind Turbines, Economic Feasibility, Net Present Value, Internal Rate of Return, Simple Payback Period

1. Introduction

In Myanmar, about 70% of its population lives in dispersed communities of rural areas and only 26% of the population has accessed to electricity [1, 2]. The provision of an electricity supply to the rural areas is still difficult and costly, and extension of the main grid over difficult terrain is not generally economic for small power demand. Hence, to solve the urgent electrification problem of rural consumers spread throughout Myanmar, the government is trying to promote renewable energy system especially in rural areas. For raising the living standard and improving the economy status of rural areas, the government has mainly laid down and pursued the planning and policies for rural-electrification with renewable energy to manage environment and strengthen the science and technology. The renewable energy sources in Myanmar are not only hydropower and biomass, but also wind, solar, and other types of renewable energy. At present, 71% of the electricity generation is from hydropower, 25% of electricity is from gas and coal is 4% of electric power sectors [3]. Due to the seasonality of hydropower production and inadequate transmission and distribution infrastructure, Myanmar has taken steps to explore the resource of biomass, solar and wind. The potential of wind energy in Myanmar has not been yet fully explored due to the lack of reliable and historical wind data. Although the early data on potential availability of wind energy in Myanmar is around 365.1 terawatt-hours per year, the data is insufficient to evaluate and select the suitable sites for the wind power project development. At present, a few numbers of small wind turbines and only one project of wind-solar hybrid system have been installed. To be more developed in wind energy application; this research will lead to introduce selection of promising sites on wind energy and economic assessment of wind project for rural electrification in Myanmar.

For the economic feasibility study of wind project, RETScreen International Wind Energy Project Model can be used world-wide to be able to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for central-grid, isolated-grid and off-grid wind energy projects, ranging in size from large scale multi-turbine wind farms to small scale single-turbine wind-diesel hybrid systems [4]. This can serve as the tool of wind farm feasibility study such as 90MW wind farm in northeastern Thailand, 2011[5]. Some other researchers [6-12] have used RETScreen for various wind energy related analyses. Baris Ozerdem et al. [6] have collected the wind data by two masts located in different coordinates on case study area, campus area of Izmir

Institute of Technology, which is in Urla county, Izmir, Turkey. To create wind energy map, the collected data between July 2000 and January 2003 were evaluated by WindPro software. Corresponding to the wind energy map, potential wind farm site was considered on technical and economical parameters with three different scenarios. For economical consideration to NPV, IRR and SPB criterial of project was investigated with respect to different characteristics of wind turbines and installed capacity by using RETScreen that was concluded, the larger the installed capacity, the smaller the generation cost per kWh from studying in a potential wind farm site, Izmir, Turkey. Erik E. Nordman's study [7] has used the Solar and Wind Energy Resource Assessment (SWERA) data set for wind resource assessment of Kenya's tea sector and found that site is suitable for development. For economic analysis of wind power project in the potential site, life cycle cost of energy at this location was estimated to be $0.156/kWh on the base case of 750kW wind turbine with positive NPV under a wide range of assumption by using RETScreen. Khalid Mohamed Nor et al. [8] have assessed the techno-economic potential wind turbine generators sites in Malaysia based on numerical weather prediction (NWP) models. Shafiqur Rehman [9] has performed for 30MW installed capacity wind farms at five coastal locations in Saudi Arabia by using RETScreen software. Among the five proposed areas, Yanbo and Dhahran would be wind park development considering with 1500, 1000, and 600 kW machine. Sad Diaf et al. [10] have presented a potential and economic analysis of a 10MW wind farm at Adrar in the southern region of Algeria. This study was based on a wind data source from Algerian Meteorological National Office during the period 1977-1988. From the summarize result, Vestas V90/2MW and Nordex N80/2500 wind turbine were adapted for power production in the site of Adrar and the cost per kWh were obtained between 0.0408$/kWh and 0.0525 $/kWh. Emmanuel Yeboah Osei and Eric Osei Essandoh [11] have determined in feasible wind power project,50MW grid-connected wind power plant at Mankoadze in the Central Region of Ghana. Van-Tan Tran and Tsai-Hsiang Chen [12] have designed 99MW wind farm capacity with 60 individual units of 1.65 MW Vestas wind turbine for Bac-Lieu wind farm located at Vinh-trach-Dong, Bac-Lieu, Vietnam. This research carried out wind energy potential and wind farm economic analysis by WAsP 10.0 and RETScreen International software, respectively. All these studies have common purpose to predict energy production and investigate cost related issues by selecting site and suitable wind turbine for wind energy project development.

In this paper, 600kW proposed wind project is demonstrated for the application of rural electrification of Myanmar. For wind resource assessment, MERRA reanalysis data set is based on throughout the entire country. According to the assessment results extracted from ArcGIS tool, Myanmar has low wind speed. Due to the applications of isolated-grids and off-grids are suitable for small scale wind turbine project [13,15], this paper hands out economic feasibility study of wind power project connected with isolated-grid in the promising sites by using RETScreen tool. For the village level case, the RETScreen proposed model highly focuses on the lowest cost of energy matching with wind data of promising areas and wind turbines characteristics in the paper. The economic feasibility study will be approached to the development and usage of wind power for rural electrification in Myanmar with respect to fulfill the government policy, promoting the rural electrification by renewable energy.

2. Materials and Methods

2.1. Preliminary Wind Resources Study

Site selection is the major step of the wind power project that mainly involves large scale wind resource assessment. The specific wind data at least one-year (on- site) measurements are required to determine the proper sites that can generate the sustainable output. It is required to verify by direct measurement with high tower mast to get long term data acquisition. However, in Myanmar, available data is still in a generalization. Therefore, wind data (from 1979 to present) was downloaded from Modern Era Retrospective-analysis for Research and Application (MERRA), published by NASA's Global Modeling and Assimilation Office, as a reference of long term data. The use of MERRA reanalysis data can lead to an improvement in accuracy for pre-estimation of energy production in this study. The MERRA data are considered at 50m height above ground level (a. g .l). The temporal and spatial resolution is 1-hourly and 2/3° long× 1/2° lat native grid (540 ×361 global grid points). The higher spatial and temporal resolutions of MERRA reanalysis data allow a better representation of local wind climate. After recording weather data of MERRA and using topographical data of Digital Elevation Model, ASTER DEM (30m), wind power density map of Myanmar can be predicted by using ArcGIS software mapping as shown in Figure. 1.

and Bago Region. The wind power density (WPD) in these areas is in quite low range from 10W/m^2 to 50W/m^2. The moderate wind power density found in Sagaing, Mandalay, Magway Regions and Mon State where are located in central and south eastern part of Myanmar. The moderate wind power density is from 20 to 80W/m^2. The highest wind power density of Myanmar (20-126W/m^2) is found in coastal area of Yakhine State, Ayeyarwaddy, Yangon and Tanintharyi Regions.

2.1.1 Best Potential Wind Energy Resources Sites in Myanmar

State/ Region	WPD (W/m^2)	Class/Description
Kachin, Kaya, Kayin, Chin, Shan, Bago	10-50	1/ Poor (0-200)
Sagaing, Mandalay, Magway, Mon	20-80	1/ Poor (0-200)
Yakhine, Ayeyarwaddy, Yangon, Tanintharyi	20-126	1/ Poor (0-200)

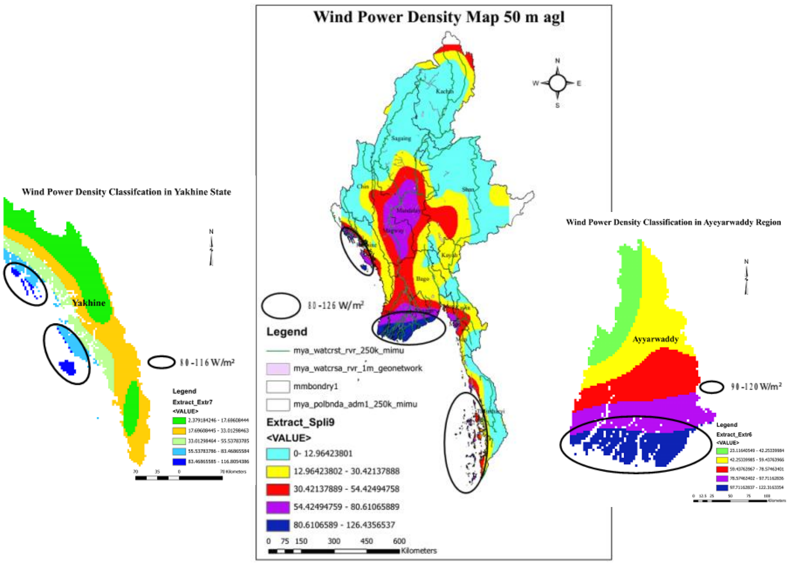


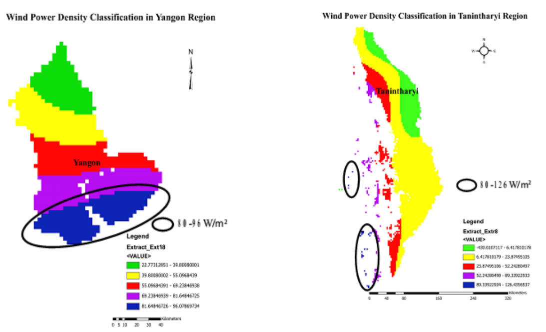
Fig.1. Wind Atlas of Myanmar

The wind power density map at 50m altitude above the ground can be performed as a good indication of the wind energy potential and can assist for the finding of proper sites preliminarily. Five different colors represent the wind power density from the lowest value to the highest. From the interpretation of wind atlas result, Myanmar has wind power density of less than 80 W/m^2 widely spread in the entire country but the strongest is located in coastal area (i.e. west, south and southwest part of Myanmar), which is up to 126W/m^2. According to the map, the wind power density can be classified with regarding to seven States and seven Regions of Myanmar described in Table 1.

Table 1. Wind Power Density in Myanmar

The lowest wind power density is located in Kachin, Kaya, Kayin, Chin, Shan States, which are the hilly regions

According to the preliminary resource assessment, the potential wind resources for project development are found in Yakhine, Ayeyarwaddy, Yangon and Tanintharyi which lie in a 2,832km long coastal strip facing the Bays of Bengal and Andaman Sea. The most promising site is located in southern tip of Tanintharyi where the estimated wind power density approaches 126.44 W/m^2. The second highest wind power density is in Ayeyarwaddy with approximately 122.32 W/m^2, followed by Yakhine with 116.81 W/m^2 and Yangon with 96.08W/m^2. The highest wind power density of these areas (≥80W/ m$^{2)}$ is described with the oval shape symbol as shown in Figure. 2.



(a) Yakhine (b) Ayeyarwaday

(c) Yangon (d) Tanintharyi

Fig.2. Wind Power Density Maps of Yakhine, Ayeyarwaddy, Yangon and Tanintharyi

The highest wind power density areas presented with oval shape are the most suitable sites for wind farm development. Due to these four areas lie in class one (0-200 W/m^2) or better, it is not economical class to set up utility-scale wind project in these areas. It is suitable for small scale wind turbine project with the applications of isolated-grids and off-grids. Low speed wind turbine generator is suitable for the development of wind farm in these sites to attain economic feasibility. Therefore, the second part of this article presents detail economic assessment to approach in promising four regions. To evaluate more precisely, some of the cities are selected from these regions with regard to the aspects of power demand based on a number of households and feasibility of setting-up isolated-grid. The selected sites are Arakan for Yakhine State, Pathein for Ayeyarwaddy, Yangon for Yangon and Ye for Tanintharyi Regions and economic assessments are investigated in these cities.

2.2. Economic Feasibility Analysis of Wind Energy Project

This content will act as a feasibility study including an economic assessment to predict the commercial viability of the project. The promising sites with the greatest wind resources are selected for additional economic analysis in RETScreeen software. RETScreen is an Excel-based modeling tool for pre-feasibility and feasibility studies of renewable energy and energy efficiency projects. In RETScreen model, there are six worksheets such as Energy model, Equipment data, Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis), Financial Analysis and Sensitivity & Risk Analysis (Sensitivity). Economic analysis of the project is conducted to run the worksheets step by step in RETScreen[17].

According to one of the suggestions arising from the wind resource study of previous section, the specified areas are likely to be facilitating the isolated-grids and other off-grid used for village power application. Therefore, this paper describes the development of wind farm with isolated-grid as the basis parameters for rural electrification. Each site is analyzed with the characteristic of turbine models, cost and financial parameters to obtain minimum unit cost for priority of village electrification.

2.2.1. Site and Data Description in RETScreen

Referring to wind power density results for selected cities, wind power densities are 120W/m^2, 125W/m^2, 100W/m^2 and 130W/m^2 for Arakan, Pathein, Yangon and Ye. These wind power density values are set in RETScreen Energy Model as input wind data in terms of selected cities because wind power density is a good indication of a site's wind energy potential. This value combines the effect of wind speed distribution which depends on wind speed and air density. From these factors, wind power density has already been calculated for each area based on air density of 1.225 kg/m³, corresponding to standard sea level pressure and a temperature of 15°C. Wind shear exponent is assumed as 0.14, which is a good first approximation when the site characteristics has not yet to be determined. Shape factor of 2.0 is assumed for Weibull wind distribution for each potential site. To calculate the losses of coefficient (C_L) expressed in Eq. (1), specify array loss, airfoil loss and miscellaneous loss are specified in RETScreen models.

$$C_L=(1-\lambda_a)\times(1-\lambda_{s\&i})\times(1-\lambda_d)\times(1-\lambda_m) \quad (1)$$

In which, λ_a = Array loss, $\lambda_{s\&i}$= Airfoil soiling and icing loss, λ_d = Downtime loss, λ_m = Miscellaneous loss

For isolated-grid, the model computes with the set data of 98% wind energy absorption rate, 2% of array loss keeps below 5%, 1% airfoil soiling of typical values range from 1 to 10%, 3% downtime loss of typical values range from 2 to 7% of gross energy production and 2.2% miscellaneous loss of typical values range from 2 to 6% of gross energy production according to the RETScreen Software online user Manual guide book for wind energy project model [18]. All these input parameters are used in Energy model worksheet of RETScreen for the potential sites.

2.2.2. Selection of Wind Turbines

The selection of turbine or suite of turbines is essential task for the particular project.

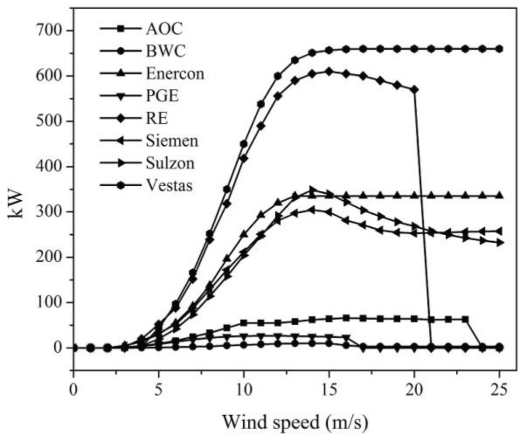
Table2. Selection Wind Turbine Generator Characteristics from RETScreen Model

As the selected sites are generally poor in wind power density with class one (0-200W/m^2), small scale rated power wind turbine is suitable for utilization of village electrification with isolate-grid or off-grid.

Fig.3. Power Curves for Selected Eight Wind Turbines

Name	No:of WTG	kW	Hub height (m)	Rotor diameter (m)	Swept area (m^2)
Altanic Orient(AOC 15/50-25m)	12	50	25	15	176.7
Bergey Windpower (BWC EXCEL-30.5m)	60	10	30.5	7	38.5
Enercon-33-50m	2	330	50	33.4	876.2
Enrgie (PGE 20/25-25m)	24	25	25	20	314.2
RE Power 48	1	600	50	48.4	1839.8
Siemen (AN BONUS 300kW Mk III-30m)	2	300	30	33.4	876.2
Sulzon (S.33/350-50m)	2	350	50	33.4	876.2
Vestas (V 47-40m)	1	660	40	47	1734.9

Therefore, wind turbine load is assumed about 600kW with isolated-grid in RETScreen model to find the economic evaluation of each potential site. Because of the low wind speed condition and connection to the isolated-grid, eight wind turbine models are selected ranging from 10kW to 660kW capacities. For the proposed project (600kW- load size), 12 units of 50kW wind turbine (Altanic Orient AOC 15/50-25m), 60 units of 10kW wind turbine (Bergey Windpower BWC EXCEL-30.5m), 2units of 330kW wind turbine (Enercon-33-50m), 24 units of 25kW wind turbine (PGE 20/25-25m), 1 unit of 600kW wind turbine (RE Power 48), 2 units of 300kW wind turbine (Siemen ,AN BONUS 300kW Mk III-30m), 2units of 350kW wind turbine (Sulzon (S.33/350-50m)) and 1 unit of 660kWwind turbine (Vestas (V 47-40m) are selected from product data sheet of RETScreen[18]. These turbine models are different types such as higher rating for standalone system, medium scale and small scale for wind farm. The power curve of these turbines is shown in Figure. 3. These types of wind turbine can operate at 3m/s and the rated wind speed is 10m/s. The technical data of the selected wind turbine models is summarized in Table 2.



For Equipment data of Energy model worksheet, the price of wind turbine is set at 1350$/kW which is taken as average between the minimum of 700$/kW and 1600$/kW.

From the selected wind turbine, the gross energy production can be calculated with the Eq. (2).

$$E_G=E_U C_H C_T \tag{2}$$

In which, E_U is the unadjusted energy production, and C_H= P/P_0 (P is the annual atmospheric pressure at the site and P is the standard atmospheric pressure of 101.3 kPa).

And C_T = T_0/T (T is the annual average absolute temperature at the site and T_0 is the standard absolute atmospheric temperature of 288.1K).

The annual average atmospheric pressure and annual average wind temperature of each site are used from the RETScreen online weather database. Pressure adjustment coefficient and temperature adjustment coefficient are also automatically calculated by the software. The capacity factor can be calculated as the ratio of the energy produced by wind turbine to the energy produced by the operating wind turbine at the rated power throughout the time period expressed in Eq. (3).

$$CF=(E_A/(P_T\times T))\times 100 \tag{3}$$

In which, CF is the capacity factor, E_A is the actual energy produced by the wind turbines, P_r is the rated power capacity of the wind turbines, T is the duration of operation in hours. In the models, the gross annual energy production (MWh) and the capacity factor can be calculated for eight types of wind turbines in each site.

2.2.3.Cost of Wind Project Development

For the Cost Analysis worksheet, assumption input parameters of cost reference are selected from RETScreen case-study cost model of wind energy generation projects. Total initial cost estimation is presented in Eq. (4).

$$\text{Total initial cost} =(FS) + (PD) + (E) + (PS) + (BM) \tag{4}$$

İn which, FS is cost related to feasibility studies, PD is cost related to project development, E is cost related to engineering, PS is cost related to the power system, BM is cost related to the balance of the system and miscellaneous. For calculating the total initial cost, Feasibility study, Development, Engineering, RE equipment, Balance of plant, Miscellaneous are identified depending on the number of the wind turbines. Due to Renewable Energy Policy of Myanmar is still in a state of drafting, the input cost parameters are set up as the assumption data in the model. When the policy is promulgated as legal frame work, the input cost parameters will be set in accordance with the legal framework instead of assumption.

To establish the RETScreen Financial analysis model for selected sites, the assumption of input parameters for Cost analysis model are reference from RETScreen case-study cost model of wind energy generation projects and the list of main model parameters are shown in Table 3.

Table3. Main Input of Assumptions Cost Value in RETScreen Model

Input parameters	Cost	Selected value	Acceptable range
Feasibility study	\$35,300	2.7%	1 to 7 %
Project Development	\$54900	4.1%	4 to 10%
Engineering cost	\$54600	4.2%	1 to 5%
Power System	\$860,000	65.1%	47 to 71%
Balance of System & Miscellaneous	\$15,787	23.9%	13 to 22 & 2 to 15%
O & M parts of labor	\$47,662	-	15%
Inflation rate (%)	-	2.0%	2 to 3%
Discount rate (%)	-	11.5%	3 to 18%
Debt ratio (%)	-	60%	50 to 90%
Debt interest rate (%)	-	7%	-
Debt term (year)	-	10yrs	-
Project life (year)	-	25yrs	20 to 30 yrs

The operation and maintenance cost is assumed as 15% of the total cost. Due to Transmission and distribution (T&D) loss of 10 to 20% in grid located in developing countries, 8% T&D losses are assumed in this cased study. Some other requirements factors are defined reference from the RETScreen case-study model.

These above parameters are used to calculate unit cost of energy (GC) and net present value (NPV) in the RETScreen Financial Model. The unit cost of energy is determined by Eq. (5).

$$GC = ACC/AEP + O\&M + FC \qquad (5)$$

In which, ACC is the annual capital cost (\$/yr), AEP is the annual energy production (kWh/yr), O&M are operation and maintenance cost (\$/kWh) and FC is the financing cost (\$/kWh). Net present value is a powerful indicator of the viability of the project according to the relation of the benefit (B), the cost (C), the period (n) and the discount rate (r) as presented in Eq. (6).

$$NPV = \Sigma(B - C)/(1+r)^n \qquad (6)$$

As the cost analysis base models are built up with assumption, there is no economic incentive (carbon credits, production tax credits, grants, etc.). These will be adjusted to persuade the investors referring to future policy. Tax and insurance related issues are not included in order to make the analysis less complicated.

3. Summary of Output Results

In the base case(600kW), Energy model, Equipment data, Cost analysis, Greenhouse gas emission reduction analysis (GHG Analysis), Financial Summary and Sensitivity & Risk analysis worksheets are operated in RETScreen models by using the above important input parameters such as wind resource data of each site, parameters of selected eight wind turbines and cost estimation key parameters of the project.

Due to matching between potential resource site and characteristics of wind turbine is crucial role of cost benefit project, appropriate wind turbine is needed to select for each site. Therefore, the wide range of scales from 10kW small scale to 600kW standalone wind turbines are chosen in the base models for each site. The result between wind turbine and energy price for four sites under study is shown in Figure. 4.

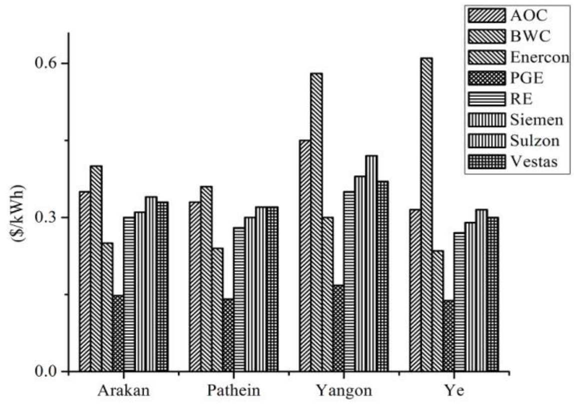


Fig. 4. Cost of kWh for Four Sites and Eight Wind Turbines

The bar graph in Figure.4 indicates that the best wind turbine is Enrgie (PGE 20/25-25m) for each site with the lowest price of 0.148$/kWh, 0.141$/kWh, 0.171$/kWh and 0.138$/kW for Arakan, Pathein, Yangon and Ye, respectively. In case of using wind turbine Bergey Wind power (BERGEY BWC EXCEL 30.5m, 10kW), the cost of kWh is the highest as 0.4$/kWh, 0.36$/kWh, 0.58$/kWh and 0.61$/kWh. This type of wind turbine (10 kW rating and 60 wind turbines) is not suitable to install in each site but it is appropriate for standalone battery charging system in rural areas. The use of Enercon is not as cheap as PGE. The other types of wind turbines (AOC, Siemen, Sulzon, RE and Vestas) are also moderate price to install wind energy system in each proposed site. From this result, the lowest price of the generated kWh can be considered in terms of matching between site and wind turbines.

Due to the models are preferable for reducing energy costs of wind power production in rural electrification, Energie (PGE 20/25-25m) is chosen for the lowest cost per unit at each site. In the case of equal load (600kW), 25kW wind turbine (PGE) is suitable and recommended for setting up the wind farm with 24 units in each site. Besides, PGE wind turbine can provide the highest capacitor factor which is one of the indicators for assessing the performance of wind turbine. The capacity factors of this type of wind turbine in each site are 23.2%, 24.3%, 20% and 24.9%, respectively. Therefore, annual electricity output can be calculated with the power curve data of the turbine and energy output curve for each site (Arakan, Pathein, Yangon, Ye) corresponding to an annual average wind power density of 120W/m^2, 125 W/m^2, 100 W/m^2 and130W/m^2. For 600kW wind farm in each site, the maximum annual energy output of 55MWh, 57MWh, 47MWh, 59MWh can be produced from this type of wind turbine. The annual energy output and capacity factor are shown in Figure. 5 from the selected wind turbine.

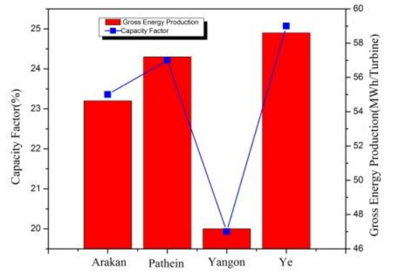


Fig.5. Gross Energy Production and Capacity Factor for PGE Wind Turbine at Each Site

Moreover, this type of wind turbine can reduce the greater amount of GHG emissions than the other types of wind turbines. The annual reductions of GHG in each site are 411 tCO_2, 430.1 tCO_2, 354.8 tCO_2 and 440.8 tCO_2. And the lowest export rate of each site are 0.148$/kWh, 0.141$/kWh, 0.171$/kWh and 0.138$/kW. In Figure.6, the annual reduction of GHG and the lowest export rate are described for each site.

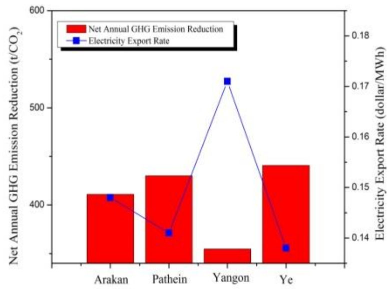


Fig.6. Annual GHG Reduction and Cost of kWh for PGE Wind Turbine at Each Site

From all these factors, PGE is the best suitable type of wind turbine for proposed wind farm (600kW) in each site with the lowest cost of energy, highest capacity factor, maximum energy production and the greatest amount of GHG reduction. After selecting the proper wind turbine for each site, the details of economical values of the net present value (NPV), internal rate of return (IRR), simple payback period (SPB) and the other values of cost are evaluated in Financial analysis worksheet. Due to NPV, IRR and SPB are essential criteria of cost effective of the project, these parameters are extracted from RETscreen models. Regarding to the lowest cost of energy in each site, RETScreen models calculate the NPV of 251.753$, 247.688$, 248.252$ and 251.699$. The required minimum IRR value is evaluated as 19% for each site. And simple pay back year is found in 10 years for each site.

Therefore, in the base model of proposed project (600kW), the result of NPV value is found in positive between site and the cost of energy. These positive values of NPV indicate that the project is feasible in comparing with negative value of NPV that would not be economically efficient. Corresponding to the required minimum value IRR is 15% for most of energy projects, the required IRR value can be investigated in 19% for each site. According to repayment periods less than 10 years, which makes the unattractive investment, SPB is determined in 10 years for each site. All the results of economic feasibility are summarized as in positive cash flow rate. Figure. 7 describes the cumulative years to positive cash flow in case of positive NPV, IRR 19% and SPB 10 years for each site.

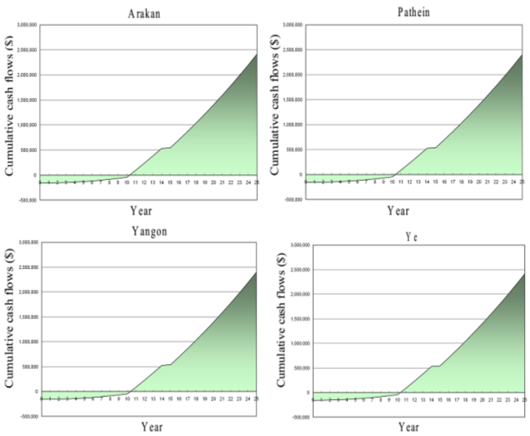


Fig.7. Positive Cumulative Cash Flow

From the positive cash flow rate resulted in Figure.7, it can be concluded that the proposed models can be economically feasible for each site. In fact, the proposed models can be a reasonably realistic picture of the project. However, they do not provide sufficient detail for a project-specific analysis because the key parameters are uncertain. The parameters impact on NPV and energy prices. Therefore, some of key parameters of the project are considered again with sensitivity analysis.

3.1. Sensitivity Analysis Performance

In addition, a sensitivity analysis is conducted to test the effects of several key parameters on NPV and cost of energy. In the sensitivity worksheet of the model, NPV of each site can be calculated by varying the key parameters of ±20% discount rate, debt ratio, debt interest rate, debt term and cost of energy. These key parameters impact on between NPV and energy price. The parameters of feasibility, development, engineering components are taken as the same case as the previous base case. IRR value and SPB period are also constant like the base case. The sensitivity analysis results for each site is summarized in Table 4.

When the electricity export rate is decreased to -20% of base case, the values are 118.40$/kWh in Arakhan, 112.80$/kWh in Pathein, 144$/kWh in Yangon and 110.40$/kWh in Ye, such values are lower than the base case in each site.Simultaneously, the key parameters are varied in -20% of base case. In -20% of base discount rate, NPV values are the lowest in each site. Similarly, when debt ratio is varied in-20% of base, NPV values are negative in each site such as -60,179$, -63,431$, -6,021$ and -60,223$ in Arakan, Pathein, Yangon and Ye, respectively. When debt interest rate is varied in -20% of base, NPV value is positive. But it is small amount

			Arakan		
Parameter	-20%	-10%	Base Case	10%	20%
Electricity export rate	118.40	133.20	148	162.80	177.60
Discount rate	$78,814	$171,108	$251,753	$316,275	$370,311
Debt ratio	$$-60,179	$95,787	$251,753	$407,719	$563,685
Debt interest rate	$8,924	$136,460	$251,753	$372,807	$493,626
Debt term	$-48,458	$102,027	$251,753	$400,755	$549,067
			Pathein		
Electricity export rate	112.80	126.90	141.00	155.10	169.20
Discount rate	$74,843	$167,094	$247,688	$312,194	$366,277
Debt ratio	$-63,431	$92,129	$247,688	$403,248	$558,807
Debt interest rate	$5,672	$126,802	$247,688	$368,366	$488,748
Debt term	$-51,710	$98,369	$247,688	$396,284	$544,190
			Yangon		
Electricity export rate	136.80	153.90	171	188	205.20
Discount rate	$75,394	$170,393	$248,252	$312,760	$366,793
Debt ratio	$-62,980	$92,636	$248.252	$403,868	$559,484
Debt interest rate	$6,123	$127,309	$248.252	$368,956	$489,424
Debt term	$-51,259	$98,876	$248,252	$396,904	$544,866
			Ye		
Electricity export rate	110.40	124.20	138	151.80	165.60
Discount rate	$78,761	$173,811	$251,699	$247,688	$251,753
Debt ratio	$-60,223	$95,738	$251,699	$407,659	$563,620
Debt interest rate	$8,880	$130,411	$251,699	$372,747	$493,561
Debt term	$-48,502	$101,978	$251,699	$400,695	$549,002

and not workable. When debt term is varied in -20% of base, NPV is negative.

Table 4. Sensitivity Analysis on NPV of Each Site Varied ±20% in Key Model Parameters

Therefore, key parameters (discount rate, debt ratio, debt interest rate, debt term) cannot be identified for the project in each site although the lowest electricity export rate can be reached at -20% condition.

In the case of -10% decreased price from the base condition, electricity export rate is also lower. At these values of electricity export rate, the key parameters are also varied in -10% of base case. In this condition, NPV value is still less. This condition cannot support to consider the feasible project.

When the electricity export rate is increased to 10% of base case, the energy price is higher. In this condition, the key parameters are also varied in 10% of base values. From this result, NPV value is going to be higher. This effect can support to the benefit of project. However, the energy price is higher level for rural electrification. And also, 20% increase to electricity export rate and key parameters values make maximum NPV value for the project. Although the greatest NPV is more profitable, the highest energy price can't be able to support the rural electrification.

From the result of sensitivity analysis, the key parameters of base case are optimum condition for rural electrification. The energy price is not too high and NPV value is positive, which can be feasible for the proposed project in each site. Therefore, the result of the pre-feasibility of suitable wind resources and promising economic analyses can be targeted on site-specific investigations. And also, the decisions can make reasonable site-specific feasibility analyses for future. The purpose of this study is to expand energy, especially electricity access in rural areas. In doing so, alleviating energy poverty will be addressed by enhancing wind energy project in remote area where wind resource is available.

4. Conclusions

Nowadays, Myanmar has organized the National Energy Management Committee (NEMC) and Renewable Energy development is one of the objectives of that committee. The government tries to set up rural electrification system mostly with wind, solar and biomass. For this reason, application of wind energy is also the important criteria. Renewable energy policy was initiated and drafted by Ministry of Science and Technology. Renewable policy is also the important factor for design and economic assessment to the wind farm. The incentive criteria such as carbon credit, production tax credit, grant, etc. will draw the attention of the developer and vary the unit price of wind project. Therefore, this paper focuses on preliminary study for the future development of wind energy in Myanmar. The paper highlights to transmit the wind energy to promising areas and identify the potential regions which should be further investigated in detail for site-specific feasibility analysis.

The wind atlas map, proper site selection and economic assessment will be applicable for potential investor who finds the right business model. In the proposed wind farm, 24 units of 25kW wind turbine (PGE) can provide the unit price of 0.148$/kWh for Arakan, 0.141$/kWh for Pathein, 0.171$/kWh for Yangon and 0.138$/kWh for Ye. It is more economic and affordable price in comparing with diesel generator price of 0.3$/kWh. The load size of the project can be adjusted with the demand of rural electrification and this paper will guide how to assess the economic feasibility on selected sites.Therefore, the decisions can make reasonable site-specific feasibility analyses for future. On the other hand, to construct the detail wind farm, the result of map will be required to check in comparison with on-site measuring data and observed the error percentage. By setting up wind mast in proposed areas and comparing with MERRA data, Wind Atlas of Myanmar will be created to find out micrositing in evaluation of the very good wind penetration source in Myanmar. Thus, this paper represents the opportunity in terms of development of wind resource assessment, technological innovation, and feasibility study on wind project, economic survey and resource efficiency for the sustainable development of rural communities in Myanmar.

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References

[1] Asian Development Bank: Energy Sector Initial Assessment, Myanmar, October 2012.

[2] Win Khaing, "Renewable in Myanmar Energy and Rural Development", 2008 TCDPAP & FIDIC/ASPAC Seoul Conference, 2008.

[3] Tint Lwin Oo, "Over View and Status of the Power Sector in Myanmar, Training on International Centre for Hydropower", 13-14, Feb, 2013, Nay Pyi Taw, Myanmar.

[4] RETScreen International Clean Energy Decision Support Centre, Wind Energy Project Analysis Chapter, Canada: 2004.

[5] Prachuab Peerapong, Bundit Limmeechokchai, 90 MW Wind farm feasibility study and site selection in northeastern Thailand:The renewable energy project under CDM, CTC 2011.

[6] Baris Ozerdem, Serra Ozer, Mahir Tosun, “Feasibility study of wind farms: A case study for Izmir, Turkey”, Journal of Wind Engineering and Industrial Aerodynamics, vol. 94, pp.725–743, April 2006.

[7] Erik E. Nordman, “Energy transitions in Kenya’s tea sector: A wind energy assessment”, Renewable Energy, vol. 68, pp. 505-514, February 2014.

[8] Khalid Mohamed Nor, Mohamed Shaaban, Hasimah Abdul Rahman, “Feasibility assessment of wind energy resources in Malaysia based on NWP models”, Renewable Energy, vol.62, pp.147-154, July 2013.

[9] Shafiqur Rehman, “Prospects of wind farm development in Saudi Arabia”, Renewable Energy, vol.30, pp. 447–463, April 2005.

[10] Said Diafa, Gilles Nottonb, Djamila Diafa, “Technical and economic assessment of wind farm power generation at Adrar in Southern Algeria”, The Mediterranean Green Energy Forum 2013, MGEF-2013, Energy Procedia, vol. 42, pp. 53-62, Novenber 2013.

[11] Emmanuel Yeboah Osei , Eric Osei Essandoh, “RETScreen Assessment of Utility Scale Wind Power Generation Based on Historical Wind Speed Data-the Case of Mankoadze in the Central Region of Ghana”, Research Journal of Applied Sciences, Engineering and Technology, vol.7(21), pp. 4593-4600, June 2014.

[12] Van-Tan Tran, Tsai-Hsiang Chen, “Assessing the Wind Energy for Rural Areas of Vietnam”, International Journal of Renewable Energy Research, vol.3,No.3, pp. 523-528, June 2013.

[13] U.S Department of Energy, Wind Energy Resource Potential, Energy Efficiency and Renewable Energy Wind and Hydropower Technologies Program, 2006.

[14] True Wind Solutions, LLC Albany, Wind Energy Resource Atlas of Southeast Asia, New York: September 2001.

[15] D. Elliott, M. Schwartz, R. George, S. Haymes, Wind Energy Resource Atlas of the Philippines, National Renewable Energy Laboratory, February, 2001.

[16] RETScreen International Clean Energy Decision Support Centre: Clean Energy Project Analysis, RETScreen Engineering and Cases Textbook. 3rd ed., Canada, 2004.

[17] RETScreen International Clean Energy Decision Support Centre: RET Screen Software Online User Manual; Wind Energy Project Model, Canada, 2004.

[18] Product data, www.retscreen.net, March 2004.

[19] http://hedataanalysis.com/link.html. [accessed in 26.9.2013]