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VIABILITY OF WIND TURBINE TO DESALINATE WATER FOR DRINKING

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Abstract: **This study aims at assessing the viability of wind energy in Nigeria to desalinate water through reverse osmosis technology. Burutu which has been identified with shortage of drinking water as a result salt water intrusion from the ocean. Data used for this study was obtained from National Aeronautics and Space Administration and Nigerian meteorological Agency and analysed using a self-developed excel spread sheet. Other parameters such as blade diameter, cut-in wind speed, hub height, extracted from the manufacturer data sheet of the turbine chosen for this design was used to develop the formulas used in the excel sheet. Four analysis was carried out on both data. First was the estimation of wind speed in m/s at the height of 120m. Second analysis was the calculation of energy generation in kWh. Third analysis was calculation of volume of water in m^3 which can be desalinated using electricity generated from the average monthly wind speed. The last analysis is the amount of Co2 saved as a result of use of renewables as source of power. The result shows that wind speed in Burutu has an annual average wind speed of 4.53m/s from NASA and 3.20m/s from Nimet data. Average monthly energy generated in this location is 39,733kwh and an annual volume of water desalinate is 95,359m^3 with 228 tonne of CO2 saved.**

Keywords: **Desalinate, wind turbine, reverse osmosis.**

1. INTRODUCTION

Water is a very essential substance in the world. Water is life; every living organism depends on water for survival. Perhaps, without water, no living thing on earth would have existed. About 75% of the earth crust is covered with water, out of which, only 3% is available as fresh water and considered safe for drinking, domestic and for agricultural use. (Spang, 2006). Surface and sub-surface water has several uses which include, drinking, agricultural purpose, industrial application, recreation and domestic use. Demand for fresh water keeps on increasing globally, whereas sources of freshwater are now scares due to increase in the world population, advancement in agricultural and industrial activities, demand for natural resources and impact of climatic change. Most water sources has been exploited and severely contaminated.

Provision of potable water has been a major challenge to many parts of the world, among which, central part of Africa, Middle East, parts of Australia and America. Recent research have shown that quite a number of areas in the North- east and south- west sedimentary belt of Nigeria also have saline water formation. The saline water occurs in artesian spring, small pond, boreholes and dug wells. (Abiola, et al., 2016). Provision of Potable water for these areas has become an issue. Reclamation of sea and brackish water through desalination process is foreseen as a good option.

Desalination technology simply means the process of recovering pure water from saline water through the use of different forms of energy. Depending on the salinity of the water sources, saline water is classified as either brackish or seawater. Desalination technologies are used for both fresh water recovery and also for waste water treatment. (Scrivani, et al., 2007).

Major problem/ limitation of desalination technologies is high energy demand, an attempt to explore renewable sources of energy for desalination is foreseen to be sustainable in future production of freshwater.

1.1. PROBLEMS SPECIFICATIONS

Nigeria has a coastline that is approximately 1000 km long with the Atlantic Ocean, which has border with some states in south-west and south-south region of Nigeria. The coastline is covered by two major sedimentary basins, Niger delta and the Benin basin. Intrusion of saline water has occurred into the aquifers of both basins which lead to abandoning of boreholes drilled in those areas due to saline test of the water. Provision of portable water for inhabitant of such communities has become a major challenge due intrusion of the salt water (Oteri & Atolagbe, 2003).

Most part of Nigeria is faced with electricity problem which lead to grounding of many industries. According to (Aliyu, et al., 2015), only 40% of Nigerians are connected to the national grid, and even with that, they still experience power outages. Hydropower is the major source of the national grid aided with hydrocarbon resources. Use of fossil fuel to generate electricity does not only contribute to CO_2 emission but leads to fluctuation in price of petroleum resources as well as political instability in the oil rich region.

1.2 AIMS AND OBJECTIVES

The main aims of this work is to assess the viability of wind energy to desalinate water for drinking in Nigeria, as well as to encourage the utilization of wind, as source of energy in Nigeria, and reduced the country's dependency on fossil fuel through assessing the potential of Wind to power desalination systems in Nigeria in other to provide water to communities with poor drinking water, and has no connection to the national grid or low power outages. This also include to decide if the chosen state/villages is suitable location for installation use of wind turbine to generates electric power that can be used to desalinate water.

The work target at providing water in a simple and environmental friendly technology for communities where both electricity and freshwater is limited in supply.

In other to achieve these aims, the following approach will be adopted:

- Wind powered reverse osmosis desalination technology will be considered
- Use of wind data to determine power output that will be generated at a particular height of wind turbine.
- Mass of CO_2 saved.
- To calculate the volume of water produced from the generated power.

2. MATERIALS AND METHODOLOGY

2.1 SITE SELECTION.

To Select a sites for installation of wind turbine, many factors are put into consideration such as, superior of wind speed, good road access, supportive land holders, and low population density. The objective of this work is to use theoretical geographic information and wind data from some selected areas to determine how much power can be generated from wind speed in such location and the quantity of water the power can desalinate, the CO2 saved. Wind speed of Burutu, a locality from the southern geopolitical zones obtained from NIMET and NASA is used to see if it can generate an energy that is capable of powering a desalination plant.

2.2 DATA COLLECTION

This study includes analysis of wind data from NASA and NIMET wind data is considered for this purpose.

An average monthly wind speed recorded at the height of 10m was obtained from Nigerian Meteorological Agency.

Table 1,monthly average wind speed (KNOTS). Key: 1 Knots= 0.514m/s (NIMET, 2017)

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Burutu	3.00	4.00	4.00	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00

2.3 GEOGRAPHY AND CLIMATE OF DELTA STATE

Delta state is in south-south geopolitical region of Nigeria which lies between longitudes 5 and 6^0 45'E and latitude $5A^0$ and $6A^0$ 30'N, with a total land mass of 16,842 sq.km..

In recent times, exploitation of oil and gas flaring has caused a serious ecological problems, causing serious environmental problem. The consequences include the poor quality portable water, killing of aquatic life and vegetation and reduction in soil fertility.

2.4 WIND DATA OF BURUTU COMMUNITY IN DELTA STATE.

NASA website provides meteorological data of any chosen location in the world ones the coordinates, longitude and the latitude of the location is known. Monthly average wind speed of Burutu village in Delta state for the average 10 years is obtained at the height of 10m. This data are compared with that of NIMET and also an estimate at the height of 120m is calculated. This community is identified of not having good potable water as result of saline water yielded by the boreholes. (Oteri & Atolagbe, 2003).

Table 2. Monthly average wind speed of Burutu at 10 m height

Lat. 5.25 Lon. 5.54	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	2.49	2.69	2.49	2.19	2.00	2.43	2.83	2.91	2.61	2.21	2.02	2.28	2.42

2.5 SELECTION OF WIND TURBINE.

Selecting a particular type of wind turbine is based on certain factors such as wind speed of the site, purpose of the design, availability of space/land, machine price, availability of the turbine spare parts, authenticity of the machine and the professionals that can fixed the machines when it break. Wind speed varies from location to the other, for this reasons wind turbine is design to suit all this conditions. For the purpose of this study were the interest is how much energy can be generated from wind speed of the selected location and volume of water the energy generated can desalinate using revers e osmosis method.

Therefore factors considered for the selection of the turbine for this design is, priority of wind speed in the selected location, therefore a turbine with a lower cut-in speed was considered. Rated power was also considered as the design is not a wind farm but a single turbine that is capable of carrying out the task.

Gamesa wind power capacity of rated 2.0 MW, cut-in wind speed of 2.5m/s, turbine hub height of 120m, and the cut-out speed which is the maximum wind speed the turbine can withstand before it shutdown is 25m/s as the characteristics that is required is chosen for this design. The figure, below is the machine power curve which is part of the manufacturer's data sheet.

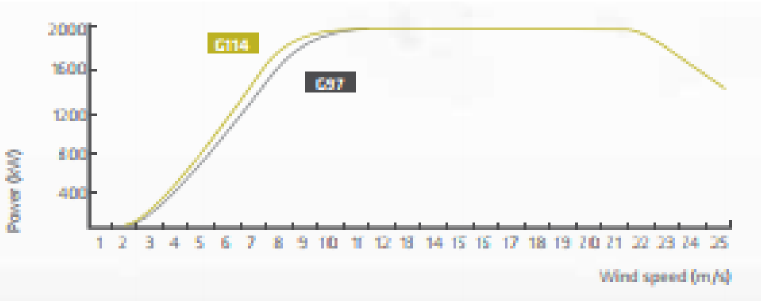

Figure 1. Wind turbine power curve provided by the manufacturer's data sheet.

From the figure it can be seen that the turbine begins to generate power, when the speed is 2.5m/s, and keeps increasing the energy generated as the wind speed increases. It then maintains a constant generation when the speed is at 10m/s to 23m/s before start going down. From the literature reviewed no part of Nigeria that has the possibility of having the speed above 24m /s. Therefore, this turbine will serve the purpose neglecting all other factors.

2.6 ESTIMATION OF WIND SPEED, AT DIFFERENT HEIGHT

Speed of wind is a very important parameter for estimation of energy yield of wind turbine. Wind speed measurement varies at different location and increases as the height increased. For this study wind data at the height of 10m was obtained from NASA and NIMET and estimated calculation at 120m height was generated using the 10m height data. As indicated above the data collected is at the height of 10m and the turbine selected is above that, a correction factor is required to estimate the wind speed at 120m hub height. Hellmann altitude formula can be used to calculate wind speed at a new height. Equation below shows the Hellmann formula.

$$v_{h,new} = v_h(\frac{h_{new}}{h})^{\alpha}$$ …………………Equation (1)

Where is $V_{h,\ new}$ is the wind speed at new height (mean)

$h_{new\ =}$ is the new height

V_h = average speed at the reference height

h= reference height and

α = Hellmann exponent.

An excel sheet developed was used to insert the Hellmann formula and calculate the new speed, tables below shows the result obtained at the calculated new height of 120m using the NASA and NIMET data. The figure below explained the graphical comparison of the wind speed of the two sources of data.

3. RESULT AND DISCUSSION

CALCULATION OF WIND SPEED OF BURUTU AT THE HEIGHT OF 120M

Table 3. calculated monthly average wind speed of Burutu at 120m height using NASA data.

Lat. 12.87 Lon. 11.04	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
year Average	4.63	4.94	4.62	4.16	3.85	4.53	5.15	5.27	4.82	4.19	3.88	4.29	4.53

Table 1 . Calculated monthly average wind speed of Burutu at 120m height using NIMET data.

Lat. 12.87 Lon. 11.04	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
year Average	3.09	3.95	3.95	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.20

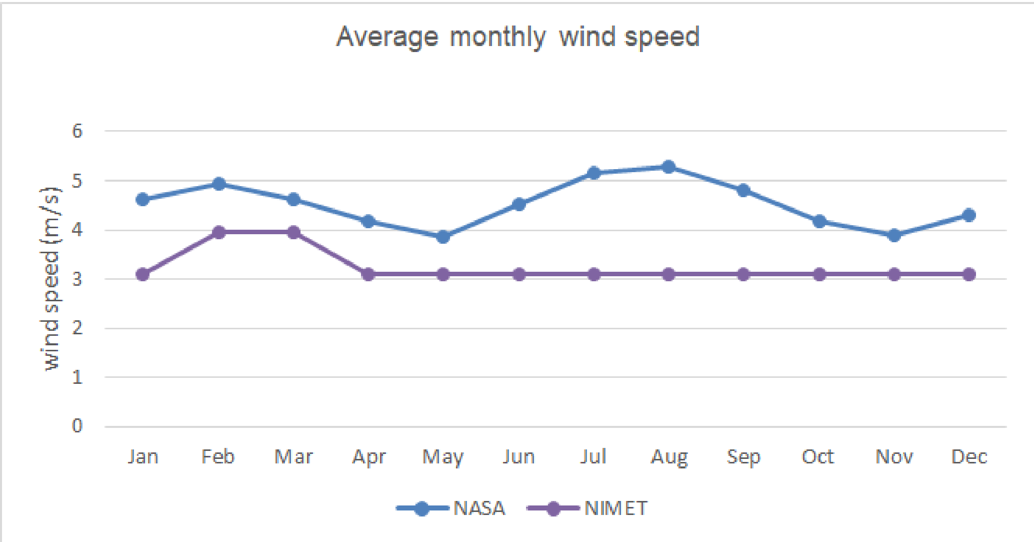

Figure 1. Average Monthly wind speed of Burutu at 120m

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Figure above shows a computed wind speed at the heigth of 120m height in burutu which was used in calculating the electrical power output. it can be obseverd from the result obtained from the new height in the choosen site are within the operating condition of the selected turbine who has cut-in wind speed of 2.5m/s. This is promising as all year round the wind speed did not drop below 3m/s for both data. The NASA looks more promising at this altitude as the minimum speed is 3.85m/s in the month of May, which is far above the cut-in speed for the turbine in question. Looking at the graph, it can be seen that in the early start of the year for both source of data it was increasing, then start to decrease in the same month of March which is towards the raining period, for the NIMET data the wind speed maintains a regular speed for the rest of the year. While in the case of NASA, at the start of the raining season the wind speed start to increases again until it reach the highest point of 5.27m/s in the months of August. This indicates that wind speed in this location is more during the raining season. For this design, the period at which the wind speed is high, it means more energy will be generated and is at the time when more water needed because of the warm weather and other activities such as farming. As the speed begings to fall, toward the end of the raining season, less energy is going to be generated, the period is more cooler as in the case of Nigeria which signifies less water is need by the community. For this case NASA data can be considred good for this location to acommplish this aim.

3.1 CALCULATION OF ENERGY YIELD OF BURUTU

The energy yield was calculated using an excel spread sheet considering the average monthly wind speed of the chosen locations, diameter of the selected wind turbine blade, and the tower height, air density, Hellman coefficient, betz limit and the conversion/ under speed assumed to be 10% respectively .

Table 5. Manufacturers specification of the selected turbine, used in the calculation

Eficiency (CP)		kg/m^3	m	m		m^2	%	%
Cp	C	ρ	D	r		A	Losses	Losses
Betz lin	Hellman C	Air density	Blade diameter	Blade radius	pi	Swept area	Conversion	Over/Underspeed
0.4	0.4	1.2	114	57	3.14	10207.03	10	10

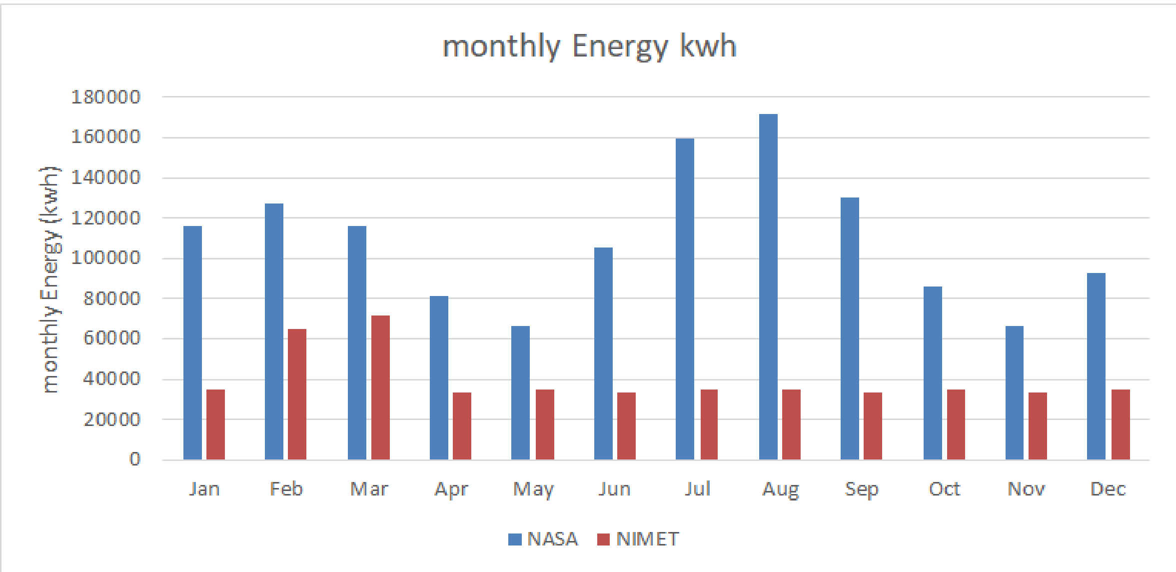

Figure 3. Monthly electrical energy produced by one turbine

The selected wind turbine opted for this study would produce around 476,793kwh a year using the NIMET and 1,316951 kWh from the NASA data. More electrical energy would be harvested in the months July and August as for the NASA data as higher wind energy is available during these months, while the NIMET data indicated that February and March is when more energy will be harvested. The difference between this two sources of data is too significant which is about 840,158kWh. Looking at the average monthly energy that is produced in this location is 39,733kWh, it can be seen is possible of having a reasonable energy all year round since the wind speed is at the generating speed of 2.5m/s as specify by the manufacturer's data sheet.

3.2 VOLUME OF WATER DESALINATE

The volume of water desalinated is calculated from the excel spread sheet considering the energy yield from the average monthly wind speed of the chosen locations. For the purposed of this study reverse osmosis method of desalination is whose energy demand of 2- 5kwh/$m^{3.}$ The actual energy generated from each month was divided but the number of hours required to desalinate 1m^3 of water. Figure below present a graph which compares the volume of water produced per month from the energy generated from both data.

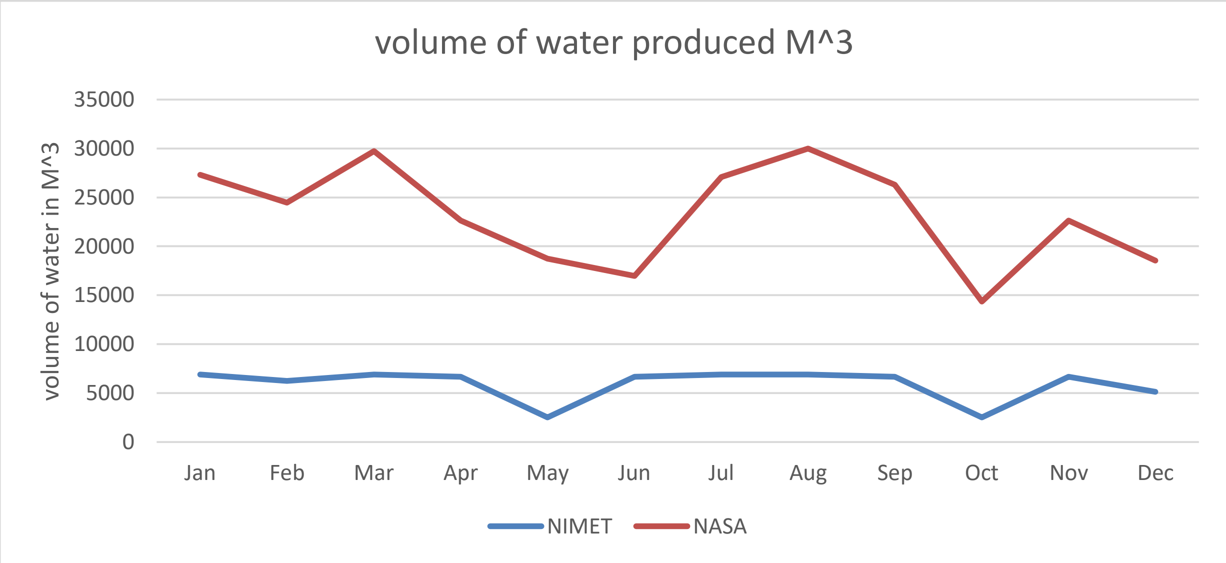

Figure 4. Volume of water produced per annum.

From the graph above, the volume of water desalinated from the energy generated it can be observed more volume is obtained during the raining season for both data. The volume start increasing at the beginning of the raining period that is May to august when it reach the peak before start decreasing, for the NASA data but in the case of NIMET the peak is at dry season between February and March.

This report the monthly amount of CO2 saved is calculated using excel electrical power output calculator by multiplying the actual power in Kwh by 0.48(turbine generates 4.8 million units of electricity each year).

Table 6, below show the amount of Co2 and heat removed from the environment per annum obtained through the calculation from the electrical power calculator.

Table 6

Locations	Co_2 saved (Kg)		Heat saved (kwh)	
	NIMET	NASA	NIMET	NASA
Burutu	222,886	630,120	1,430,378	3,938,247

4. CONCLUSION

This study was carried out to examine the viability and possibility of using wind turbine as source of power for desalination plant in other to proffer solution to saline water challenges in location along the coast.

Nigeria currently does not have a wind farm that is fully operating despite wind potentials in several part of the country. There is a clear policy available to public but its implementation is very slow. Nigeria has set up a research development centre for wind energy, but faces a big setback, such inadequate funding, unskilled manpower, and lack of public awareness. Currently Nigeria has few turbines installed in some parts whose application is for water pumping and small-scale electricity generation. Significant findings from this research are summarised and concluded as below.

Wind speed in the Burutu southern part of Nigeria has the capability standalone wind turbine project to power desalination plant, the average wind speed per annum in the region is 3.2m/s Burutu, at the height of 120m using NIMET data for this design.

Volume of water produced per annum in Burutu is 262,550m^3 which is capable of providing 276, 875 people a portable drinking water per annum on the average of 8 litres per day for each person from energy generated from NASA and NIMET is producing 95,359m^3 per annum, capable of providing 100,948 people in a year. It can be concluded that it is possible to carry out this project in Burutu considering the number of people that will have a clean water to drink in a year.

CO2 emission saved by an average 2MW turbine in Burutu is 228.89 tonne.

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