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# Studies of Wind Resources in Umudike, South East Nigeria-An Assessment of Economic Viability

A.D. Asiegbu and G.S. Iwuoha
Michael Okpara University of Agriculture, Umudike, Nigeria

**Abstract:** Studies of the wind resources in Umudike community have been done over a ten-year period (1994-2003) as an assessment of economic viability. Analysis based on IEC wind speed correction report shows that the wind present in the community is economically viable from a hub height of 67m and above. From this height the wind can deliver to a wind turbine an average annual speed of 5.36 $ms^{-1}$ (12 mph) and more study is both revealing informative.

**Key words:** Wind, wind-speed, hub-height, economic-viability, wind-turbine

## INTRODUCTION

Umudike is a town in Umuahia, Abia State, Southeast Nigeria, found within latitudes 5°26' and 5°43'N and within longitudes 7°2' and 7°35'E (MLS, 1999), Umudike as a town has a sizable population and houses the National Root Crop Research Institute (2005) which is known to have made break throughs in root crop researches. It houses the Michael Okpara University of Agriculture, which at the time of this report is the only University of Agriculture within the southeastern region of the country. Umudike is no doubt a center of scientific and agricultural activities. Obviously the young University of Agriculture has great potentials for growth, not only in the areas of scholastic pursuits but also in research and extensive agricultural endeavors. All these will eventually impact on energy resources within the community.

Therefore, the wind power available at the Umudike community should be considered as a subsidiary measure to boost the energy resource of the community. However, this will only be possible if the wind available within the community is economically viable. This stduy therefore, assesses the economic viability of the wind resources in Umudike for proper and cost effective use.

In the 1990s wind was the fastest growing energy technology in the world, growing at the annual rate of 22.6% as noted by Robins (2000). Today it is still the fastest growing energy technology and the growth rate has experienced tremendous boost of up to 25% per year (Warren, 2004). Wind is the most cost effective energy resource (Thresher, 2004). In line with the Kyoto protocol, Millais reported that wind power was one of the leading global solutions to tackle climate change.

**Theoretical background:** Wind, generally described as air in motion is usually unpredictable and varies from place to place and from moment to moment. Wind speed is the rate at which air flows past a point above the earth's surface. It can be quite variable and is affected by trees, buildings, hills and valleys. Wind is a diffuse energy source that cannot be easily contained or stored for use elsewhere. This is the major challenge in harnessing wind energy.

According to Iowa Energy Center (IEC) report , wind is a by-product of solar energy (IEC, 2000). Approximately 2% of the sun's energy reaching the earth is converted into wind energy. The surface of the earth heats and cools unevenly, creating atmospheric pressure zones that make air to flow from high-to-low pressure areas. Trade winds on a tropical island are fairly dependable, providing a nearly constant wind flow throughout the day and night. Wind speeds can range from gale force to total calm within a 24 h period.

In general, daily and seasonal changes as well as wind directions are important considerations while siting wind systems. Wind speed increases with height, the approximate increase of speed with height according to IEC report for different surfaces, is obtained with the expression (IEC, 2000):

$$V_2 = V_1 (h_2/h_1)^n \quad (1)$$

Where, $V_1$ is the reference wind speed at height $h_1$ above the ground, $V_2$ is the speed at a second height $h_2$
n is the exponent determining the wind change

Typical values of n for different surfaces are given in Table 1.

**Corresponding Author:** A.D. Asiegbu, Michael Okpara University of Agriculture, Umudike, Nigeria

Table 1: List of n for different surfaces from IEC (2000)

| Surface | n |
|---|---|
| Smooth surface ocean, sand | 0.10 |
| Low grass or fallow ground | 0.16 |
| High grass or low row crops | 0.18 |
| Tall row crops or low woods | 0.20 |
| High woods with many trees, suburbs, small towns | 0.30 |

It should be noted that the velocity expression of Eq. (1) is based on values of average speed not instantaneous values. Also siting within dense vegetation such as a forest or an orchard require establishment of a new effective ground level at approximately the height where the branches of adjacent trees touch, below this level there is a little wind. In a dense cornfield wind, this height would be the average corn height or average height of the tree canopy for a forest area.

In areas of high wind, wind power can be quit reliable and inexpensive. However, for wind energy to be economically viable, it has to deliver to a wind turbine an average annual wind speed of at least 12mph (5.36 $ms^{-1}$) and above (IEC, 2000).

In general, power is defined as work done per second (Nelkon and Parker, 1995). Therefore, wind power is a measure of the energy derivable from the wind per unit time. The amount of power available in the wind according to IEC publication is determined by the expression (IEC, 2000):

$$P = \frac{1}{2} \ell A v^3 \tag{2}$$

Where, P is wind power in Watts
$\ell$ is air density in $kgm^{-3}$
A is the rotor area of the blade in $m^2$
V is the wind speed in $ms^{-1}$

Air density varies with elevation and temperature. Equation (2) shows that wind power is a function of the third power of the wind speed.

## MATERIALS AND METHODS

Materials used for this work include wind speed data obtained from the weather station of the National Root Crop Research Institute (NRCRI) Umudike. This covered a ten-year period from January 1994 to December 2003. Data were measured on daily basis using the Beaufort Scale of Wind Force (BSWF) shown in Table 2.

Table 3 shows the monthly and yearly wind speed averages of the Umudike community expressed in Beaufort numbers from January 1994 to December 2003. For the purposes of this work average values expressed in Knots and other units were converted to SI units before substitution in the requisite calculations.

Table 2: Specification of the Beaufort scale of wind force, obtained from NRCRI, Umudike(2005)

| Beaufort no. | Description of wind | Mean speed in Knots |
|---|---|---|
| 0 | Calm | 0 |
| 1 | Light air | 2 |
| 2 | Light breeze | 5 |
| 3 | Gentle breeze | 9 |
| 4 | Moderate breeze | 13 |
| 5 | Fresh breeze | 19 |
| 6 | Strong breeze | 25 |
| 7 | Moderate gale | 31 |
| 8 | Fresh gale | 37 |
| 9 | Strong gale | 44 |
| 10 | Whole gale | 51 |
| 11 | Storm | 59 |
| 12 | Hurricane | Above 63 |

Table 3: Umudike monthly and yearly average wind speed number (in Beaufort), obtained from NRCRI, Umudike

| Month | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|
| January | 1.9 | 1.9 | 1.8 | 1.6 | 1.8 | 1.7 | 1.7 | 1.9 | 2.0 | 1.7 |
| February | 1.7 | 1.8 | 1.9 | 1.7 | 1.6 | 1.4 | 1.9 | 1.9 | 1.7 | 1.9 |
| March | 2.1 | 1.9 | 1.9 | 1.8 | 1.5 | 1.8 | 1.8 | 2.1 | 1.7 | 1.8 |
| April | 2.2 | 1.9 | 1.8 | 1.8 | 1.6 | 1.6 | 1.9 | 1.9 | 1.8 | 1.7 |
| May | 2.0 | 1.9 | 1.9 | 1.7 | 1.5 | 1.9 | 1.9 | 1.9 | 1.8 | 1.7 |
| June | 2.1 | 2.0 | 1.9 | 1.7 | 1.3 | 1.7 | 1.9 | 1.9 | 2.0 | 1.8 |
| July | 2.0 | 2.0 | 1.9 | 1.7 | 1.6 | 1.8 | 1.9 | 1.9 | 2.2 | 1.8 |
| August | 2.0 | 2.0 | 1.8 | 1.7 | 1.7 | 1.8 | 2.0 | 2.0 | 1.8 | 2.1 |
| September | 1.8 | 1.9 | 1.9 | 1.5 | 1.5 | 1.7 | 1.9 | 1.9 | 1.9 | 1.8 |
| October | 1.8 | 1.8 | 1.7 | 1.5 | 1.6 | 1.7 | 1.7 | 1.7 | 1.6 | 1.8 |
| November | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.6 | 1.6 | 1.8 | 1.5 | 1.7 |
| December | 2.2 | 1.5 | 1.6 | 1.5 | 1.5 | 1.7 | 1.6 | 1.6 | 1.8 | 1.7 |
| Average | 1.94 | 1.84 | 1.80 | 1.66 | 1.55 | 1.70 | 182 | 1.89 | 1.78 | 1.82 |

Also the average pressure and temperature values at the site for the year 2003 and 2004 as recorded at the station stood at the figures of 750 mmHg and 32°C, respectively.

The data of Table 3 were based on a hub height of 6m and were corrected in this research for higher heights. This was done to determine the height within the locality above which the wind speed will be economically viable. Thus the minimum hub-height for which the wind speed will deliver at least a speed of 12mph (5.36 $ms^{-1}$) to a wind turbine was determined. This was done using Eq. (1). Hence from this height and above the wind resource in the community is economically viable and below this height it is not.

## RESULTS AND DISCUSSION

From Table 3, the average wind speed of the community is obtained approximately as 2.0 Beaufort number. This value according to Table 2 corresponds to a speed of 5.0 Knots. Thus the type of wind prevalent in the area is light breeze. Umudike has many trees and suburbs, therefore the exponent, n for determining the wind speed change suitable for the community according to IEC is 0.30. This is shown in Table 1.

Looking at Eq. (2) we observe that speed is the most important parameter of the wind that affect the power content of the resource. If we secure a higher value for the speed, we secure a higher power from the resource. This can be achieved through the speed correction expression of Eq. (1).

But 1.0 Knots is equivalent to 0.51444 $ms^{-1}$. Therefore a speed of 5.0 Knots is equal to about 2.6 ms-1. To determine the minimum height for which the wind speed in the community can deliver a speed of up to 12 mph (5.36 $ms^{-1}$) to a wind turbine, we re write Eq. (1) as follows:

$$V_2 = V_1 X^n$$

Where $X = h_2/h_1$
Substituting values we obtain;
$X^n = V_2 / V_1$
$X^{0.3} = 5.36 / 2.6$
$X^{0.3} = 2.06$.

Taking logarithms of both sides, we have;
$0.3 \log X = \log 2.06$
$\text{Log } X = (\log 2.06) / 0.3$
$\text{Log } X = 1.046224068$

Thus:
$X = 11.12305457$m
But $X = h_2/h_1$, where $h_1 = 6.0$m
Giving $h_2 = 6 \times 11.12305457$
Hence $h_2 = 66.73832744$, which is approximately 67m

From this calculation, we observe that the minimum height for which the wind speed will attain a value of 5.36 $ms^{-1}$ and hence economically viable is 67m. This appears to be high because what is prevalent in the area is light breeze.

## CONCLUSION

In this research, the wind resources present at Umudike community have been studied using a ten-year wind speed data (1994 to 2003). Studies done at a height of 6m gave the average wind speed of the community as 2.6 $ms^{-1}$. However at this height, this figure of wind speed according to IEC report is not economically viable for harnessing. For economic viability, the wind should be able to deliver to a wind turbine at least an average annual speed of 5.36 $ms^{-1}$.

Since wind speed increases with height, for economic viability the height at which the wind will attain this value of 5.36 $ms^{-1}$ was determined as 67m. Thus the wind resource in the community is economically viable from a height of 67m and above. Hence wind machines sited within the community should have a hub height of 67m and above. This study is revealing and informative.

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