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Assessment of Wind Energy Technologies in Nigeria

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Abstract: The wind energy resource situation in Nigeria including the estimated potential, economic competitiveness, technical assessment, cost comparison of wind energy technologies with other energy technologies, available amount of the resource and global wind energy utilization are presented in this study. The status of the database is discussed indicating its degree of adequacy and an identification of the gaps. Wind speeds in Nigeria range from a low 1.4-3.0 m sec^{-1} in the Southern areas and 4.0-5.12 m sec^{-1} in the extreme North. Wind speeds in Nigeria are generally weak in the South except for the coastal regions and offshore locations. In Nigeria, peak wind speeds generally occur between April and August for most sites. Initial study has shown that total actual exploitable wind energy reserve at 10 m height may vary from 8 MWh year^{-1} in Yola to 51 MWh year^{-1} in the mountain areas of Jos Plateau and it is as high as 97 MWh year^{-1} in Sokoto. Hence, Nigeria falls into the poor/moderate wind regime.

Key words: Energy potentials, wind, energy, database, resource, wind regime, economic competitiveness, global

INTRODUCTION

Effectively all renewable forms of energy with the exceptions of geothermal and tidal are types of solar energy. It is the power that radiates from the sun that enables renewable energy technologies to exist. In a single hour, the sun radiates approximately 175 billion kWh of energy and approximately 1-2% of this is converted into wind energy (Manwell *et al*., 2002). This is an enormous resource to be utilized.

The earth orbits the sun and receives light and heat from the sun daily. It is the heat that the earth receives that creates wind. Figure 1 shows that the surface of the earth has a temperature gradient. The majority of the heat from the sun is received at the equator and it gradually reduces towards both poles. This temperature gradient creates wind. In the warmer regions of the earth, the air is hot and is therefore at a high pressure, conversely at the colder regions, the air is at a low pressure. Wind is the movement of air from areas of high pressure to low pressure. Hot air is lighter than cold air and will rise until it reaches an altitude of approximately 10 km, it will then spread to the North and South poles. However, the wind flow is not as simple as that if this was just the case the wind would always flow from the equator in the direction of either pole. The reason the wind does not just flow to either pole is due to the rotation of the earth. As the earth is spinning, it creates a force known as the Coriolis (1932) force as shown in Fig. 2. The Coriolis force was discovered in 1835 by a French mathematician Gustave Gaspard Coriolis (1792-1843). It is a known visible phenomenon where the rotation of the earth causes any

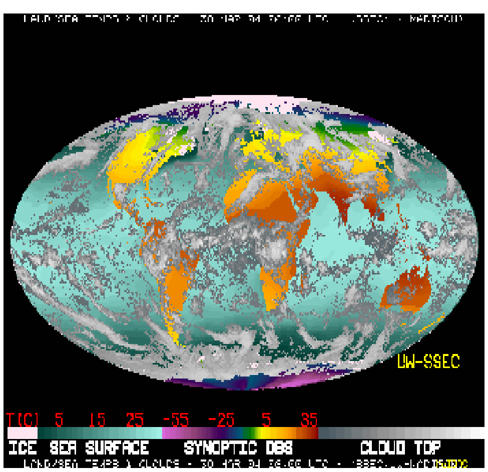

Fig. 1: Satellite image showing earth surface temperature variations

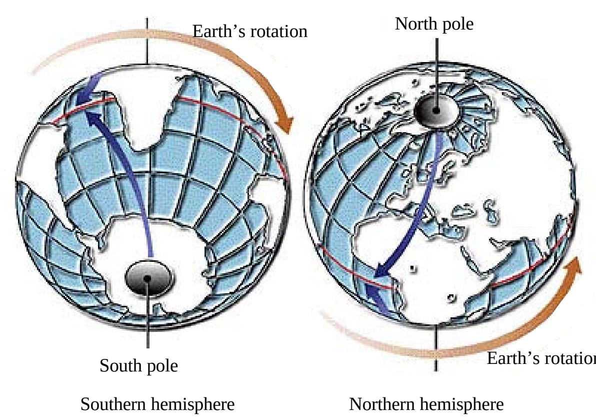

Fig. 2: Coriolis force

Table 1: Predominant wind directions

Latitude	Direction
90°-60° N	NE
60°-30° N	SW
30°-0° N	NE
0°-30° S	SE
30°-60° S	NW
60°-90° S	SE

moving object in the Northern hemisphere to be deflected to the right and any moving object in the Southern hemisphere to be deflected to the left. Visual impacts of the Coriolis force can be seen on railroad tracks where the rail on one side wears faster than the other depending upon which hemisphere.

The Coriolis force does not create wind but affects its flow. The winds primarily affected by these temperature gradients and Coriolis force occur on a large scale and are found at high altitudes above the earth. They are known as geostrophic winds. These geostrophic winds produce predominant wind directions for different regions of the earth as shown in Table 1. Wind speeds in Nigeria range from a low 1.4-3.0 m sec^{-1} in the Southern areas and 4.0-5.12 m sec^{-1} in the extreme North. Wind speeds in Nigeria are generally weak in the South except for the coastal regions and offshore locations. In Nigeria, peak wind speeds generally occur between April and August for most sites. Initial study has shown that total actual exploitable wind energy reserve at 10 m height may vary from 8 Mwh $year^{-1}$ in Yola to 51 MWh $year^{-1}$ in the mountain areas of Jos Plateau and it is as high as 97 MWh $year^{-1}$ in Sokoto. Hence, Nigeria falls into the poor/moderate wind regime.

The Nigerian Meteorological Agency carries out routine measurements and collection of wind data for the country. These records are available in its archives. There is also a wind mapping programme initiated by the Federal Ministry of Science and Technology. This research only covers ten selected sites across the country where detailed site study is to be carried out using about one year continuous data from wind measuring equipment. Only a few wind maps for limited sites are available. Hence, there is the need to develop wind maps and update existing atlas.

Wind energy utilization in Nigeria is practically minimal. The hundreds of wind pumps scattered all over the country are ill maintained and some have been abandoned. Some state governments, like Jigawa and Kano are making efforts to install new wind pumps. There is a pilot wind electricity project in existence which is the 5 kWp Sayya Gidan Gada wind electricity project at Sokoto. In addition, a 0.75 kWp wind electricity project in the center of the town is being run on an experimental basis to prove the viability of wind farming in the area. Wind energy is one of the lowest-priced renewable energy technologies available today, costing between 4-6 cent kWh^{-1}, depending on the wind resource base and financing of the particular project. The construction time of wind energy technology is less than other energy technologies, it uses cost-free fuel, the operation and maintenance cost is very low and capacity addition can be in modular form making it adaptable to increasing demand. However, several economic, policy, technical and market barriers militate against the rapid adoption of wind power in Nigeria. These barriers must be addressed if the potentials identified and the targets set for electricity from wind power are to be realized.

Resource situation: Nigeria is subject to the seasonal rain-bearing South-westerlies which blow strongly from April to October and to the dry and dusty North-East trade winds which blow strongly from November to March every year. Most areas sometimes experience some periods of doldrums in between these periods. Wind energy reserves are measured in terms of wind speeds at 10 m above sea level (Ojosu and Salawu, 1990).

In Nigeria, wind energy reserves at 10 m height shows that some sites have wind regime between 1.0-5.1 m sec^{-1}. The wind regimes in Nigeria are classified into following four regimes >4.0; 3.1-4.0; 2.1-3.0 and 1.0-2.0 m sec^{-1}. Hence, Nigeria falls into the poor/moderate wind regime. It is also observed that the wind speeds in the country are generally weak in the South except for the coastal regions and offshore which are windy. In the coastal areas and in the large areas offshore from Lagos state through Ondo, Delta, Rivers and Bayelsa states to Akwa Ibom state, potentials exist for harvesting strong wind energy throughout the year (ECN, 2004). Except for maritime activities and fishing, there is hardly any obstacle to wind farm development for near-shore wind energy farms. Inland, the wind is strongest in the hilly regions of the North. The mountainous terrains, especially in the middle belt and the northern fringes of the country where prime wind conditions may exist are to a large extent sparsely populated and extensive areas for wind energy development exist in these locations.

Estimated resource base: Due to the varying topography and roughness of the country, large differences may exist within the same locality. Hence within a few kilometers, the wind speed may vary. The values range from a low 1.4-3.0 m sec^{-1} in the Southern areas and 4.0-5.12 m sec^{-1} in the extreme North. Peak wind speeds generally occur between April and August for most sites. Initial study has shown that total actual exploitable wind energy reserve at

10 m height may vary from 8 MWh $year^{-1}$ in Yola to 51 MWh $year^{-1}$ in the mountain areas of Jos Plateau and it is as high as 97 MWh $year^{-1}$ in Sokoto (ECN, 2004).

Status of database including adequacy and gaps: Wind resource is usually expressed in wind speed (m sec^{-1}) from which energy units can be obtained. There are usually two levels of data needed for national wind energy development. At the top level is the Meso-scale (National level) data. This type of data is useful for policy and it is usually the 1st call for developers of wind energy projects. The other is the site specific local level where one obtains more detailed data based on measurements.

When a particular site appears promising for wind farm development, detailed site-specific measurements are carried out through the erection of a meteorology mast, about 30-50 m in height depending on the terrain for measuring wind speed and wind direction at different heights. Typical hub heights for wind turbines are now 60 m and it is projected to reach about 100 m by year, 2030. Actual measurements are needed because the power output of a wind farm is sensitive to wind speed being proportional to the cube of the wind speed. Thus, doubling of the average wind speed leads to an increase of the power in the wind by a factor of eight. Therefore, wind speed can determine the viability or otherwise of a wind farm project.

Detailed and reliable information about variation in wind speeds and direction over the year is therefore, vital for any prospective wind power development. Apart from the wind speed, the wind speed frequency distribution, commonly described by a Weibull distribution is also important. The Nigerian Meteorological Agency (NMA) which is the national authority, carries out routine measurements and collection of wind data for the country. The records are for the 42 Synoptic stations mainly based at the airports and urban centers. These records available in its archives (published and unpublished) give the 3-hourly records of wind, the wind speed, the prevailing wind directions, the annual mean of the percentage wind frequencies in different directions and for various speed ranges and the number of days for which the wind force is greater than No. 4 on the Beaufort scale.

The International Institute for Tropical Agriculture (IITA), Ibadan also has wind data for about four of its stations. IITA only collects wind speed at a height of 2 m. Some of the wind instruments at IITA are the Casela and Met014A cup anemometers. The wind instruments installed in each of the stations of the NMA differ. About 75% of the stations use cup generator anemometers while the remaining stations use the dine pressure tube anemometers. About 90% of the stations have ordinary wind vanes installed alongside the anemometers. The anemometers are installed at different heights due to the presence of tall buildings or trees but most are installed at 6 feet (about 2 m) height.

Hence, their data need to be harmonized for uniformity for it to be useful for the power sector. Most of the equipment used by the Nigerian Meteorological Agency and IITA are calibrated to the World Meteorological Organization (WMO) standard. There is a WMO centre for sub-Saharan Africa in Nigeria. The data collected at the observing stations are sent to the Data-returns office at Oshodi, Lagos which serves as the Data Bank for all meteorological data supervised and collected by the NMA. The data are archived both in their original manuscript form and/or in computer storage devices. The NMA computer centre is equipped with Database Management subsystems for climate computing developed by NMA. Computerization started around 1974 and has about 40 years of computerized wind data.

Available site specific level data: A major feasibility study on windmill was undertaken in Nigeria by the United Nations Development Program (UNDP) in 1984. This study on the potential for windmill application to various activities concluded that good potential exists in the semi-arid and temperate areas of the North, the middle belt and the shores of Lake Chad for such activities as small scale irrigation, domestic water pumping, livestock water supply and electric power generation. This was a desktop study. In 2003, the Federal Ministry of Science and Technology engaged a firm of consultants Lahmeyer International (LI) for its wind energy mapping programme.

This study only covers ten selected sites across the country where detailed site study are to be carried out using about 1 year continuous data from wind measuring equipment. Lahmeyer International is also to collect historical wind data, erect wind measurement masts and install wind measurement equipment on the masts for data collection and produces the zero level wind maps that indicate potential sites. The long-term wind energy potentials of these sites can then be quantified.

Gaps in available data: There are no national or local wind atlases that have been produced for Nigeria. Only a few wind maps for limited sites are available. Hence, there is the need to develop wind maps and atlases for the country that will provide information about the quantity, distribution, quality and utilization possibilities to determine the commercial feasibility of wind energy generation and decision making on investments.

Technical assessment of wind power technologies: A large amount of power is contained in the movement of air in form of wind. Harnessing of wind as a source of energy has a long history starting from the time the Persians built the first known windmills as early as 250 BC. Much later, wind energy was widely used as a source of power before the industrial revolution. However, the interest in wind technology nose-dived from the industrial revolution period when it was displaced by the more reliable and cheap fossil fuel.

In the 1970s', there was a renewed interest in wind energy technology because of the increases in oil prices which affected the economies of the industrialized countries. In the last two decades, these interests reinforced by the need for cleaner energy technologies have resulted in enormous progress on the development of wind turbine for electricity generation.

Categorization and applications of wind technology: Applications of wind turbines may be categorized as indicated in Table 2 which also shows the unit size of wind turbines that are typically applied in the different categories.

Following a decision on extending the electricity production capacity by one or more wind farms as shown in Fig. 3, one has to decide where to place the wind farms (siting), the size of the wind farms (sizing) and the optimum layout of the wind farms. The size of a wind farm is often determined with respect to a number of constraints such as planning legislation; local and national development plans and policies; land availability, access and transport infrastructure; power system present and future situation; wind turbine size; financing; electricity market and environmental impacts. Economic and financial optimum choice of wind farm size for society and investors at given conditions may vary for different sites hence, sizing and siting are integrated activities. Further, sizing involves aspects that may not easily be quantified monetarily. Wind farm site selection most often entails a comparison of selected candidate sites with respect to issues such as the possibility to obtain planning authorization and approvals; successful outcome of local hearings; potential wind energy production; environmental costs and benefits; sustainability, uncertainties and risks; availability of land and infrastructure; investments and investors; design safety, reliability and lifetime; wind farm and power system operation and maintenance, economic and financial viability (EWEA, 2002).

Table 2: Categorization of wind power systems (EWEA, 2002)

Installed power (range)	Categorization	Wind turbine (capacity)
<1 kW	Micro systems	<1 kW
1-100 kW	Wind home systems and Hybrid systems	1-50 kW
100 kW-10 MW	Isolated power systems and ecentralized generation	100 kW-1 MW
>10 MW	Wind power plants-wind farms on-land	>500 kW
>100 MW	Wind power plants-wind farms offshore	>2000 kW

Fig. 3: Wind farm

Status of wind energy technology worldwide: The status of wind energy technology in some countries in the world that are in the forefront in the use of wind energy resources and the state of the technology in the country are discussed in what follows.

Wind turbine capacity factor: Worldwide installed capacity 1997-2008 as shown in Fig. 4 with projection 2009-2013 based on an exponential fit. Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. Typical capacity factors are 20-40% with values at the upper end of the range in particularly favorable sites. For example, a 1 MW turbine with a capacity factor of 35% will not produce 8,760 MWh in a year (1×24×365) but only 1×0.35×24×365 = 3,066 MWh, averaging to 0.35 MW. Unlike fueled generating plants, the capacity factor is limited by the inherent

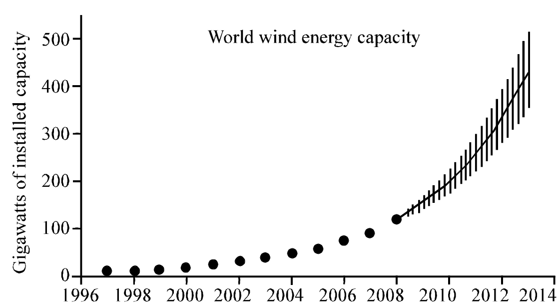

Fig. 4: Worldwide installed capacity 1997-2008 with projection 2009-13 based on an exponential fit (Lu *et al*., 2009)

properties of wind. Capacity factors of other types of power plant are based mostly on fuel cost with a small amount of downtime for maintenance. Nuclear plants have low incremental fuel cost and so are run at full output and achieve a 90% capacity factor. Plants with higher fuel cost are throttled back to follow load. Gas turbine plants using natural gas as fuel may be very expensive to operate and may be run only to meet peak power demand. A gas turbine plant may have an annual capacity factor of 5-25% due to relatively high energy production cost.

According to a 2007 Stanford University study published in the Journal of Applied Meteorology and Climatology, interconnecting ≥10 wind farms can allow an average of 33% of the total energy produced to be used as reliable, base load electric power as long as minimum criteria are met for wind speed and turbine height (Lu *et al*., 2009).

In a 2008 study released by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, the capacity factor achieved by the wind turbine fleet is shown to be increasing as the technology improves. The capacity factor achieved by new wind turbines in 2004 and 2005 reached 36%.

Global wind energy utilization: By 2010, the World Wind Energy Association expects 160 GW of capacity to be installed worldwide (EERE, 2008) up from 73.9 GW at the end of 2006, implying an anticipated net growth rate of >21% year^{-1}.

Wind accounts for nearly one-fifth of electricity generated in Denmark, the highest percentage of any country and it is 10th in the world in total wind power generation. Denmark is prominent in the manufacturing and use of wind turbines with a commitment made in the 1970s' to eventually produce half of the country's power by wind.

In recent years, the US has added more wind energy to its grid than any other country with a growth in power capacity of 45% to 16.8 GW in 2007 and surpassing Germany's nameplate capacity in 2008. California was one of the incubators of the modern wind power industry and led the US in installed capacity for many years; however by the end of 2006, Texas became the leading wind power state and continues to extend its lead. At the end of 2008, the state had 7,116 MW installed which would have ranked it 6th in the world if Texas was a separate country. Iowa and Minnesota each grew to >1 GW installed by the end of 2007; in 2008 they were joined by Oregon, Washington and Colorado. Wind power generation in the US was up 31.8% in February, 2007 from February, 2006 (Galbraith, 2008). The average output of one MW of wind power is equivalent to the average electricity consumption of about 250 American households. According to the American Wind Energy Association, wind will generate enough electricity in 2008 to power just >1% (equivalent to 4.5 million households) of total electricity in US up from <0.1% in 1999. US Department of Energy studies have concluded wind harvested in the Great Plains states of Texas, Kansas and North Dakota could provide enough electricity to power the entire nation and that offshore wind farms could do the same job.

In addition, the wind resource over and around the Great lakes, recoverable with currently available technology could by itself provide 80% as much power as the US and Canada currently generate from non-renewable resources with Michigan's share alone equating to one third of current US electricity demand (AWEA, 2009). China had originally set a generating target of 30,000 MW by 2020 from renewable energy sources but reached 22,500 MW by end of 2009 and could easily surpass 30,000 MW by end of 2010. Indigenous wind power could generate up to 253,000 MW (Jones, 2007). A Chinese renewable energy law was adopted in November 2004, following the World Wind Energy Conference organized by the Chinese and the World Wind Energy Association.

By 2008, wind power was growing faster in China than the government had planned and indeed faster in percentage terms than in any other large country having more than doubled each year since, 2005. Policymakers doubled their wind power prediction for 2010 after the wind industry reached the original goal of 5 GW 3 years ahead of schedule (Brown, 2006).

Current trends suggest an actual installed capacity near 20 GW by 2010 with China shortly thereafter pursuing the United States for the world wind power lead (Brennand, 2001). India ranks 5th in the world with a total wind power capacity of 10,925 MW in 2009 (AWEA, 2009) or 3% of all electricity produced in India.

The World Wind Energy Conference in New Delhi in November, 2006 has given additional impetus to the Indian wind industry (AWEA, 2009). Muppandal village in Tamil Nadu state, India has several wind turbine farms in its vicinity and is one of the major wind energy harnessing centres in India led by majors like Suzlon, Vestas, Micon among others. Mexico recently opened La Venta II wind power project as a step toward reducing Mexico's consumption of fossil fuels. The 88 MW project is the 1st of its kind in Mexico and will provide 13% of the electricity needs of the state of Oaxaca. By 2012, the project will have a capacity of 3,500 MW. In May 2010, Sempra energy announced it would build a wind farm in Baja California with a capacity of at least 1,000 MW at a cost of $5.5 billion. Another growing market is Brazil with a wind potential of 143 GW. South Africa has a proposed station situated on the West Coast North of the Olifants river mouth near the town of Koekenaap, East of Vredendal in the Western Cape province. The station is proposed to have a total output of 100 MW although, there are negotiations to double this capacity. The plant could be operational by 2010.

France has announced a target of 12,500 MW installed by 2010, though their installation trends over the past few years suggest they will fall well short of their goal. Canada experienced rapid growth of wind capacity between 2000 and 2006 with total installed capacity increasing from 137-1, 451 MW and showing an annual growth rate of 38%.

Particularly rapid growth was seen in 2006 with total capacity doubling from the 684 MW at the end of 2005. This growth was fed by measures including installation targets, economic incentives and political support. For example, the Ontario government announced that it will introduce a feed-in tariff for wind power, referred to as Standard Offer Contracts, which may boost the wind industry across the province. In Quebec, the provincially owned electric utility plans to purchase an additional 2000 MW by 2013. By 2025, Canada will reach its capacity of 55,000 MW of wind energy or 20% of the country's energy needs.

Nigeria wind energy utilization: Wind energy utilization in Nigeria is practically minimal relatively insignificant. The Tractor and Equipment Division of United African Company of Nigeria (UAC) started manufacturing the wind pumps in Nigeria. Test units were installed in Goronyo, Sokoto state and the UAC Agro Farms in Kedanda, Kaduna State. The project was initially successful and attracted the attention of Katsina State Government who ordered 62 units in 1989 (ECN, 2004). The high cost of each unit (>US$6,000 in 1990) coupled with difficulties encountered in maintenance limited their widespread use.

The hundreds of wind pumps scattered all over the country are ill maintained and some have been abandoned. Some state governments like Jigawa and Kano are making efforts to install new wind pumps. There are two pilot wind electricity projects in existence. The 5 KWp Sayya Gidan Gada wind electricity project at Sokoto and a 0.75 KWp wind electricity project in the center of the town near Danjawa village is being run on an experimental basis to prove the viability of wind farm in the area. The report of the Technical committee on Quantification of Energy Resources states that as far back as the 1960s', >100 wind pumps had been installed in Kano, Jigawa, Sokoto, Yobe, Katsina, Lagos (Badagry) and Plateau (Jos) states to supply water for both human consumption and livestock (European Commission, 2001; ECN, 2004; Liu *et al*., 2002).

Table 3: Cost comparison of wind energy project cost components

Countries	Investment ($ kW^{-1})	Cost generating ($ kWh^{-1})	Cost operation and maintenance cost ($ kWh^{-1})
China	1000	0.067	-
Europe	1188-1518	[a]0.054-0.066 [b]0.079-0.106	0.0158-0.0198
USA	3500	0.5-0.6	-

For Europe, investment cost lower figure is for large turbine while the higher figure is for small turbine. The investment cost for USA is for small turbine. [a]cost range for good sites; [b]cost range for bad sites (Brennand, 2001; EWEA, 2002)

Economic competitiveness: There are many factors affecting the cost of wind generation. These include investment/capital cost, operation and maintenance cost, government policy, management capacity and skill, size and capacity factor of the turbine and site of the project. The major components of the cost of a wind energy project are investment, energy generation and operation and maintenance costs.

Investment cost: The capital cost of a wind energy project is dominated by the cost of wind turbine. This alone takes about 75% of the total cost of a wind energy project. However over the last 12 years, there has been a reduction in cost by approximately 30%. The cost of a wind energy project is dependent on the size of the turbine. The smaller sizes are more expensive than the larger sizes on a per KW installed capacity basis. Also, capacity factor drives up the relative capital cost. For instance if there are two wind turbines of the same size but with different capacity factors say 30 and 60%, the relative capital cost of the one with the lower capacity factor will be >1 with the higher capacity factor. Table 3 shows an overview of investment cost for small and large wind turbine sizes for some countries and regions of the world.

Energy cost: Cost of energy generated is dependent on both turbine size and project site. Generation cost per unit energy is higher for small turbines than for large turbines. At good sites where the wind speed is higher and less intermittent, the cost of energy generation is lower than for bad sites. Table 3 shows the figures for some regions of the world.

Operation and maintenance cost: Wind energy projects generally have very low operation and maintenance cost.

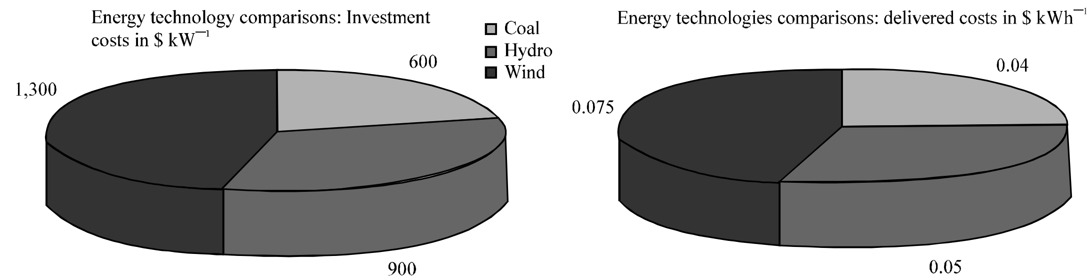

Fig. 5: Cost comparisons between wind energy and other energy technologies in China (Brennand, 2001)

For instance, cost for the 1st 2 years in Germany is about 2-3% of total investment cost. It is decreasing for newer and larger wind turbines.

Cost comparison of wind energy technology and other energy technologies: Figure 5 shows a cost comparison of both investment and generating costs between wind energy technology and other energy technologies in China. Table 3 shows that these costs for the wind energy technology are becoming competitive even with long standing conventional energy technologies. However, it should be noted that for the Nigeria case, all the costs of wind energy technology will be higher than for the countries discussed in today's market.

Benefits and limitations: Wind energy is one of the lowest-priced renewable energy technologies available today, costing between 4-6 cent kWh^{-1} depending upon the wind resource and project financing of the particular project. The construction time of wind energy technology is less than other energy technologies, it uses cost-free fuel, the operation and maintenance cost is very low and capacity addition can be in modular form, making it adaptable to increasing demand. It enhances diversification of energy carriers for the production of heat, fuel and electricity and also helps in saving fossil fuels for other applications and the future generations (Brennand, 2001).

Wind energy is fueled by the wind thereby making it a clean fuel source, non-polluting and making no demands upon the environment beyond the comparatively modest use of land area. In addition, wind turbines do not produce greenhouse gases which cause acid rain and climate change.

Wind power must compete with conventional electricity generation sources on a cost basis. Depending on how energetic a wind site is, the wind farm may or may not be cost competitive. Even though, the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment cost than fossil-fueled generators. A major challenge to using wind for electricity generation is that wind is intermittent and not be available when electricity is needed. Furthermore, wind energy cannot be stored unless batteries are used and not all winds can be harnessed to meet the timing of electricity demands.

Wind resource development may compete with other uses for the land and those alternative uses may be more highly valued than electricity generation. Although, wind power plants have relatively little impact on the environment compared to other conventional power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts and sometimes, birds have been killed by flying into the rotors. However, most of these problems have been resolved or greatly reduced through technological development or by properly siting wind plants (Brennand, 2001).

Market situation of wind power technologies: The main driver for wind power has been the need to reduce greenhouse gases emission especially carbon dioxide. More recently however, other concerns such as energy supply security have also become an important socioeconomic issue in Europe and USA. The main energy strategy of these countries is to diversify the energy supply base away from imported fossil fuels so as to minimize the impact of any disruptions. Energy supply gaps in India have also been a major market driving force for wind energy in that country.

Present demand and supply situation

Worldwide wind energy capacity: Wind power capacity has expanded around the world over the past 5 years at a very high rate of about 30% as shown in Table 4. By 2003, the cumulative installed wind energy electricity was 40,300 MW. Five countries, Germany, USA, Spain, Denmark and India are the main players.

They represent over 75% of world capacity. In terms of capacity addition Germany, USA and Spain accounts for >50% of the increase in year, 2003.

Table 4: Worldwide total installed and new capacity of wind power in 2003 (Brennand, 2001)

Countries	New capacity in 2003 (MW)	Total capacity end of 2003 (MW)
Germany	2674	14612
Spain	1377	6420
USA	1687	6361
Denmark	218	3076
India 423	423	2125
Netherlands	233	938
Italy	116	922
Japan	275	761
United Kingdom	195	759
China	-	571
Others	861	3756
World total	8344	40301

Capacity in 2003

Potential market for wind energy in Nigeria: There is no established supplier of wind turbines in Nigeria in recent times. About 20 years ago, UAC imported some wind turbines that were sold to states in the North. Given the before, there is no established significant market for wind energy in Nigeria. However, there are potential markets described below which can be developed if wind energy is to play any significant role in the nation's energy supply mix.

Agricultural activities need supply of water: A wind electric pumping system is ideally suited for irrigation and other water pumping activities required in farm settlements that are not connected to the national grid. A wind turbines rating of <10 KW is adequate for water pumping for the small agriculture settlements. This application is especially suitable for the Northern parts of the country.

Non-grid hybrid system for rural electrification: In many rural areas in Nigeria where there is no access to the national grid or the grid is remote, wind energy could provide a cost effective option for rural electrification. Since the wind energy is intermittent, they can be augmented with either a PV system or diesel generator set. Access to electricity in the rural area of Nigeria has been put to about 20%; hence this hybrid system could be hugely patronized in the country. Depending on the size of village, a wind turbine size of 100-750 KW can be installed.

Wind farms: The cost of large scale wind farm has been steadily declining throughout the last decade. Hence given a favorable wind regime, wind power can be competitive with conventional sources of power production. While 1-2.5 MW turbines are increasingly common, 3-5 MW turbines are being developed and may become common in the future. Wind farms in excess of 200 MW range are now common in Europe, USA and India. Wind farms may be grid-connected or may form the backbone of a mini grid for remote areas far away from the main grid.

Barriers to wind power technology market development: There are several economic, policies, technical and market barriers that will militate against the rapid adoption of wind power in Nigeria. These barriers must be addressed if the potentials identified earlier and the targets set for the electricity from wind power are to be realized. The barriers are identified (ECN, 2004).

Economic barriers: The capital cost of wind turbine energy is still currently above the cost of fossil fuel based base-load electric plant. One factor contributing to this is the lower capacity factor of wind power plants, i.e., around 24% compared to >70% for fossil fuel base-load plants. The lower capacity factor means that to produce a given amount of electricity, it is necessary to install 2-2.5 times more capacity than with fossil fuel plant. This tends to make wind energy more expensive in the initial phase of the life cycle, constituting a barrier to investment and economic decisions on wind energy development.

This barrier is likely to be removed in the future because the capital cost of wind power is expected to decrease in the future. A EWEA (2002) major study predicts that the capital cost of wind power will likely decrease by 30% over the next 15 years. If the cost of environmental damage by fossil fuel electricity is accounted for it is likely that the capital cost of wind power will become more competitive than it is now.

Low electricity tariff: The average electricity tariff in Nigeria is about 5 cent kWh^{-1}. It is estimated that the generating cost of electricity from wind power in Nigeria is between 8-10 cent kWh^{-1} where that of China is about 6.7 cent kWh^{-1}.

Policy and institutional framework: Although, the national energy policy recognizes the potentials for wind power, there are no specific policies or incentives for promoting wind energy. Key policy on power purchase agreement that will ensure that wind power developers will be able to sell electricity to the national grid is not yet in place. The 2005 Electricity Sector Power Reform Act reforms are yet to become effective structurally.

The coordination between Energy Commission, Ministry of Science and Technology, Ministry of Power and Steel and other agencies responsible for rural development is weak as it relates to implementing an integrated strategy for renewable energy in general and wind power in particular. None of the two energy centres with responsibility for renewable energy research and development has an appreciable wind Research and development programme due to inadequate funding. There is therefore, lack of capacity and experience in the country on wind power development.

Lack of manufacturing capability: The lack of such capability in Nigeria as at now will therefore, slow down the rapid introduction of wind power into the electricity supply mix. In addition to the lack of manufacturing capability, lack of technical capacity for maintenance of wind turbines is a major barrier to the development of wind power.

Lack of data on wind resource availability and technology: Reliable site specific data on wind resources are needed by investors to make investment decisions on wind power. Presently, such data are not readily available in the country.

There are only about ten sites where detailed data are currently being collected. This is a big barrier to the development of wind farms. In addition, there is dearth of information and data on wind technology is creating impressions that wind energy is yet to be mature.

Lack of awareness about potentials of renewable energy: Wide understanding of decision makers both in the public and private sector, especially in the financial sector is rather low. This lack of information and awareness creates a market distortion which results in higher risk perception for potential wind projects. The general perception is that wind power is not yet a mature technology, hence it is only suited for niche market and even then it will require heavy subsidy to make it viable.

CONCLUSION

The electricity produced from wind power is intermittent and variable depending on the weather. This poses some technical challenges of reliability when integrating wind power into the national transmission grid. Another barrier is related to the siting of wind turbines which has to be located in areas with good wind resources. More often than not the areas with best wind resources are often far away from load centres (usually urban settlements) where the electricity is needed and served by the national grid. Hence, there may be a need for expensive grid extension or the creation of mini grids to transmit and distribute electricity produced from wind energy.

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