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Review article

Wind energy development: Innovation and new prospective

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A R T I C L E I N F O

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A B S T R A C T

The imminent exhaustion of fossil energy resources and the increasing demand for energy were the motives for those reasonable in world to put into practice an energy policy based on rational use of energy; and on exploitation of new and renewable energy sources. After 1980, as the supply of conventional energy has not been able to follow the tremendous increase of the production demand in rural areas of the world, a renewed interest for the application of solar and wind energy has shown in many places. Therefore, the researchers and engineers began to pay more attention to wind and solar energy utilisation in rural areas. Because the wind energy resource in many rural areas is sufficient for attractive application of wind pumps, and as fuel is insufficient, the wind pumps will be spread on a rather large-scale in the near future. Wind is a form of renewable energy, which is always in a non-steady state due to the wide temporal and spatial variations of wind velocity. The need for the provision of new data stations in order to enable a complete and reliable assessment of the overall wind power potential of the country is to be identified and specific locations suggested. This article presents the background and ideas of the development of the concept as well as the main results and experience gained during ongoing projects up to now. In the world, various designs of wind machines for water pumping have been developed and some designs are presently manufactured commercially. Results suggest that wind power would be more profitably used for local and small-scale applications especially for remote rural areas. It is concluded that many parts of the world is enjoyed with abundant wind and solar energy resources.

1. Introduction

New and renewable sources of energy can make an increasing contribution to the energy supply mix of the world in view of favourable renewable energy resource endowments, limitations and uncertainties of fossil fuel supplies, adverse balance of payments and the increasing pressure on environment from conventional energy generation. Among the renewable energy technologies, the generation of mechanical and electrical power by wind machines has emerged as a techno-economical viable and cost-effective option. The provision of pumped clean water is one of the best ways to improve health and increase the productive capacity of the population. Rural access to clean water is best achieved through pumping from underground water aquifers rather than using surface water sources, which are often polluted. Because of the relatively small quantities of water required, wind pumping for village water supply and livestock watering can, is cost-effective given a good wind site. Irrigation pumping however requires large quantities of water at specific times of the year. For much of the year the pump may be idle or oversized and wind pumping for irrigation may be more difficult to justify on economic grounds. Wind energy is one of the several energy sources, alternatives to the conventional primary energy resources, which are now power man's industrial and socio-economic activities worldwide. With the notable exception of hydropower (which in fact is renewable), these primary energy resources have definite lifetimes, and depending on use rate among several other factors.

The sources to alleviate the energy situation in the world are sufficient to supply all foreseeable needs. Conservation of energy and rationing in some form will however have to be practised by most countries, to reduce oil imports and redress balance of payments positions. Meanwhile development and application of nuclear power and some of the traditional solar, wind and water energy alternatives must be set in hand to supplement what remains of the fossil fuels. The encouragement of greater energy use is an essential component of development. In the short-term, it requires mechanisms to enable the rapid increase in energy/capita, and in the long-term, we should be working towards a way of life, which makes use of energy efficiency and without the impairment of the environment or of causing safety problems. Such a programme should as far as possible be based on renewable energy resources.

Large-scale, conventional, power plant such as hydropower has an important part to play in development. It does not, however, provide a complete solution. There is an important complementary role for the greater use of small-scale, rural based and power plants. Such plant can be used to assist development since it can be made locally using local resources, enabling a rapid built-up in total equipment to be made without a corresponding and unacceptably large demand on central funds. Renewable resources are particularly suitable for providing the energy for such equipment and its use is also compatible with the long-term aims. It is possible with relatively simple flat plate solar collectors to provide warmed water and enable some space heating for homes and offices which is particularly useful when the buildings are well insulated and thermal capacity sufficient for the carry over of energy from day to night is arranged. In addition to the drain on resources, such an increase in consumption consequences, together with the increased hazards of pollution and the safety problems associated with a large nuclear fission programmes are the problems we face. This is a disturbing prospect. It would be equally unacceptable to suggest that the difference in energy between the developed and developing countries and prudent for the developed countries to move towards a way of life which, whilst maintaining or even increasing quality of life, and reduce significantly the energy consumption per capita. Such savings can be achieved in a number of ways:

- Improved efficiency of energy use, for example better thermal insulation, energy recovery, and total energy.
- Conservation of energy resources by design for long life and recycling rather than the short life throwaway product.

- Systematic replanning of our way of life, for example in the field of transport. A strong local political commitment to the environment and sustainability.

Currently the non-commercial fuels wood, crop residues and animal dung are used in large amounts in the rural areas of developing countries, principally for heating and cooking, the method of use is highly inefficient. As in the developed countries, the fossil fuels are currently of great importance in the developing countries. Geothermal and tidal energy are less important though, of course, will have local significance where conditions are suitable. Nuclear energy sources are included for completeness, but are not likely to make any effective contribution in the rural areas.

Between 1980 and 2000 governmental awareness of wind energy mainly concentrated in Denmark and Germany, where a large number of wind turbines were manufactured and installed. Nowadays, most European governments are well aware of the potential of wind energy. Generally, the development and operation of a wind farm can be subdivided into four phases:

- Initiation and feasibility.
- Pre-building (conducted by go/no-go).
- Building.
- Operation and maintenance.

Wind energy is one of the fastest growing industries nowadays. The development in wind turbine (WT) technology is not limited to the significant increase in the size of the modern units, but also includes the high reliability and availability of the current machine. Therefore, a great competition among the manufactures established on the market and newcomers in the field is witnessed nowadays. A rapid development in the wind energy technology has made it alternative to conventional energy systems in recent years. Parallel to this development, wind energy systems (WES) have made a significant contribution to daily life in developing countries, where one third of the world's people live without electricity. Many developing nations need to expand their power systems to meet the demand in rural areas. However, extending central power systems to remote locations is too costly an option in most cases. Then, autonomous small-scale energy systems can meet the electricity demand in remote locations, even though they generate relatively little power. However, even little electricity would contribute greatly to the quality of life in some places of developing countries. Being one of the most promising autonomous power technologies, wind energy applications, in the power range from tens of Watts to kilowatts, are increasingly growing in rural areas of developing countries. Technical and economical aspects of WESs should further be improved to sustain this growth.

2. Wind energy

Since early-recorded history, people have been harnessing the energy of the wind. Wind energy propelled boats along the Nile River as early as 5000 B.C., by 200 B.C.; simple windmills in China were pumping water, while vertical-axis windmills with woven reed sails were grinding grain in Persia and the Middle East. New ways of using the energy of the wind eventually spread around the world. By the 11^{th} century, people in the Middle East were using windmills extensively for food production; returning merchants and crusaders carried this idea back to Europe. The Dutch refined the windmill and adapted it for draining lakes and marshes in the Rhine River Delta. When settlers took this technology to the New World in the late 19^{th} century, they began using windmills to pump water for farms and ranches; and later, to generate electricity for homes and industry.

Wind power is the conversion of wind energy into useful form, such as electricity, using wind turbines. In windmills, wind energy is directly used to crush grain or to pump water. At the end of 2007, worldwide capacity of wind-powered generators was 94.1 Giga-Watts (GW). Although wind currently produces just over 1% of worldwide electricity use, it accounts for approximately 19% of electricity production in Denmark, 9% in Spain and Portugal; and 6% in Germany and the Republic of Ireland (2007 data). Globally, wind power generation increased more than fivefold between 2000 and 2007.

The cost of the overall system increases as the complexity of the power electronic converter increases. The intricacy of the controller design also affects cost; for example, the use of MPPT techniques would cost more than a simple lookup table method. However, higher order control and converter designs may increase efficiency of the overall system. The inclusion of a DC-boost stage helps reduce the control complexity of the grid inverter at a small increase in cost. Likewise, replacing the diode rectifier with a controlled rectifier allows for a wider range of control of both the generator and grid real and reactive power transfer. In order to maximise the benefits of the wind energy conversion system, a compromise between efficiency and cost must be obtained. A summary of the different generator–converter topologies available for wind energy conversion is shown in Table 1 (Henderson and Roding, 2004). In addition, Table 2 lists the various generators discussed in this article and outlines the advantages and disadvantages of each (Advanced Energy, Henderson and Roding, 2004).

Wind is simple air in motion. It is caused by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of very different types of land and water, it absorbs the sun's heat at different rates. Today, wind energy is mainly used to generate electricity. Wind energy is also world's fastest growing energy source and is a clean and renewable source that has been in use for centuries in Europe and more recently in the United States and other nations. Wind turbines, both large and small, produce electricity for utilities and homeowners and remote villages. Wind energy is a clean energy source as electricity generated by wind turbines do not pollute the air or emit pollutants like other energy sources. This means less smog, less acid rain and fewer greenhouse gas emissions. Every 10,000 Mega Watts (MW) of wind installed can reduce carbon dioxide (CO_2) emissions by approximately 33 MMT annually if it replaces coal-fired generating capacity, or 21 million metric tonnes (MMT) if it replaces generation from average fuel mix. Many developing countries have little incentive to use wind energy technologies, to reduce their emissions despite the fact that the most rapid growth in CO_2 emissions is in the developing world. Two related activities could give both developed and developing countries incentives to develop wind projects. The first is joint implementation, a programme under which firms from the developed countries can earn carbon offsets by building clean energy projects in the developing world. Developed nations should endorse and push for joint implementation to move from its current status to full-scale implementation.

The second activity is the World Bank's Global Environmental Facility (GEF), which can cover the incremental cost of developing environmentally benign or beneficial projects in the developing world, such as building wind projects instead of an apparently cheaper coal projects. This incentive is particularly important for countries such as China and India, which have tremendous power needs and must build energy capacity quickly at the lowest possible cost. There are numerous factors that influence the overall prospects for the wind industry, though in the end, it is the economics that will be the deciding factor (Table 3). The most important issues identified:

- Assessment of previous patterns of market development in similar markets.
- Increased engagement of utilities and large energy companies.
- National energy plans and government support for renewable energy.
- Technical development.
- Growth in market and the present dynamics of the industry.
- Information about specific large projects.
- Assessment of wind resources and how they can be used.

Economic projections are difficult at the best of times, when economies are relatively stable and a reference 'business as usual' case can be used. However, there are numerous signals that the world faces very turbulent economic conditions for a while -a credit crunch may make some projects finance difficult and the shortage of raw materials could lead to supply chain difficulties. However, the rapidly escalating price of oil is focusing a lot of attention on the price of energy and the hedge of electricity supply without a fuel cost is likely to become increasingly attractive to many companies and utilities. At some stage, rising fuel costs could lead to demand for wind energy becoming almost infinite. The main factors expected to influence the continuing growth of the wind sector are:

- The economies of the transition states (Russia and Central Asia) will start to grow and increasing energy demand in Asia and South America.
- Oil prices will continue to remain high as will demand for fossil fuels.
- Continuing competitiveness of wind with fossil fuels.
- Many countries may find they are well off their international CO_2 reduction commitments and need to install some new renewable capacity very quickly.
- Security of supply questions will continue to support wind power.

- Deregulated markets will remove excess conventional power capacity and new capacity is likely to be more expensive than wind.

Table 1
Summary of wind energy conversion systems.

Generator (power range)	Converter options	Device count (Semiconductor cost)	Control schemes
PMSG (KW)	Diode bridge/SCR inverter compensator	DC-Link cap, 12 controllable switches (moderate)	Simple firing angle control of one converter
	SCR rectifier/SCR inverter	DC-Link cap, 12 controllable switches (moderate)	Simple firing angle control of both converters
	Diode bridge/Hard-switching inverter	DC-Link cap, 6 controllable switches (low)	Power mapping technique including stator frequency derivative control MPPT, wind prediction control
	Diode bridge/DC boost/Hard-switching inverter	DC-Link cap, 7 controllable switches (low)	Vector control of supply side inverter DC Voltage control via chopper duty radio
	Back-to-back hard-switching inverters	DC-Link cap, 12 controllable switches (moderate)	MPPT, vector control of both converters
	Back-to-back hard-switching inverters (reduced switch)	2 DC-Link cap, 8 controllable switches (low)	Generator controlled through MPPT inverter current controlled through PI controllers
DFIG (KW-MW)	Diode bridge/SCR inverter	DC-Link cap, 6 controllable switches (low)	Sliding mode control
	SCR rectifier/SCR inverter	DC-Link cap, 12 controllable switches (moderate)	Dual thyristor firing angle control
	Back-to-back hard-switching inverters	DC-Link cap, 12 controllable switches (moderate)	Vector control of rotor and supply side space vector modulation or PWM MPPT, space vector control
	Matrix converter	18 controllable switches (high)	Vector control of rotor and supply side double space vector PWM switching
IG (KW-MW)	Back-to-back hard-switching inverters	DC-Link cap, 12 controllable switches (moderate)	Vector control, use fuzzy logic controllers user rotor slot harmonics and model reference adaptive system
SG 9 (KW-MW)	Diode bridge/DC boost/Hard-switching inverter	DC-Link cap, 7 controllable switches (low)	Phase angle displacement control supply voltage control
	Back-to-back hard-switching inverters	DC-Link cap, 12 controllable switches (moderate)	Supply real and reactive power control generator electromagnetic torque control

Most of these factors are favourable for the industry at the moment. There is strong political support for wind energy, both as engineering and supply chain problems that have been associated with rapid growth in the past. While wind energy can still seem a small industry compared with conventional power generation, the achievement of 1% of world electricity generation is potentially significant. In individual markets such as Denmark, Germany and Spain reaching 1% has been a breakthrough figure, establishing a critical mass and being followed by further rapid growth in each year market. If the same pattern is seen with world wind energy demand and the industry continues to establish itself as a significant player in the energy sector and pushes on rapidly to 30% of world electricity demand and beyond, then the glass should be seen as half full.

Table 2
Advantages and disadvantages of generator types.

Generator type	Advantages	Disadvantages
Permanent magnet synchronous generator	• Flexibility in design allows for smaller and lighter designs • Higher output level may be achieved without the need to increase generator size • Lower maintenance cost and operating costs, bearings last longer • No significant losses generated in the rotor • Generator speed can be regulated without the need for gears or gearbox • Very high torque can be achieved at low speeds • Eliminates the need for separate excitation or cooling systems	• Higher initial const due to high price of magnets used • Permanent magnet costs restricts production of such generators for large scale grid connected turbine designs • High temperatures and severe overloading and short circuit conditions can demagnetize permanent magnets • Use of diode rectifier in initial stage of power conversion reduces the controllability of overall system
Asynchronous generator	• Lower capital cost for construction of the generator • Known as rugged machines that have a very simple design • Higher availability especially for larger scale grid connected designs • Excellent damping of torque pulsation caused by sudden wind gusts • Relatively low contribution to system fault levels	• Increase converter cost since converter must be rated at the full system power • Results in increased losses through converter due to large converter size needed for IG • Generator requires reactive power and therefore increases cost of initial AC-DC conversion stage of converter • May experience a large in-rush current when first connected to the grid • Increased control complexity due to increased number of switches in converter
Double fed induction generator	• Reduced converter cost, converter rating is typically 25% of total system power • Improved efficiency due to reduced losses in the power electronic converter • Suitable for high power applications including recent advances in offshore installation • Allows converter to generator or absorb reactive power due to DFIG used • Control may be applied at a lower cost due to reduced converter power rating	• Increased control complexity due to increased number of switches in converter • Stator winding is directly connected to the grid and susceptible to grid disturbances • Increased capital cost and need for periodic slip ring maintenance • Increased slip ring sensitivity and maintenance in offshore installations • Is not direct drive and therefore requires a maintenance intensive gearbox for connection to wind turbine

Wound field synchronous generator	• Minimum mechanical wear due to slow machine rotation • Direct drive applicable further reducing cost since gearbox not needed • Allow for reactive power control as they are self excited machines that do not require reactive power injection • Readily accepted by electrically isolated systems for grid connection • Allow for independent control both real and reactive power	• Typically have higher maintenance costs again in comparison to that of an IG • Magnet used which is necessary for synchronization is expensive • Magnet tends to become demagnetized while working in the powerful magnetic fields inside the generator • Requires synchronizing relay in order to properly synchronize with the grid

Table 3
Market shares 2005-2007**.**

Years		**2005**		**2006**		**2007**	
Manufacturer	**Country**	**Supplied**	**Share**	**Supplied**	**Share**	**Supplied**	**Share**
Vestas	Denmark	3186	27.6%	4239	28.2%	4503	22.8%
Ge Wind	US	2025	17.5%	2326	15.5%	3283	16.6%
Gamesa	Spain	1474	12.8%	2346	15.6%	3047	15.4%
Enercon	Germany	1640	14.2%	2316	15.4%	2769	14.0%
Suzton	India	700	6.1%	1157	7.7%	2082	10.5%
Siemens	Denmark	629	5.4%	1103	7.3%	1397	7.1%
Acciona	Spain	224	1.9%	426	2.8%	873	4.4%
Goldwind	China	132	1.1%	416	2.8%	830	4.2%
Nordex	Germany	298	2.6%	505	3.4%	676	3.4%
Sinovel	China	3	0.0%	75	0.5%	671	3.4%
Others		1032	8.9%	1094	7.3%	2076	10.5%
Total		11343	98%	16003	107%	22207	112%

Wind energy is one of the low investments high yielding sources of power generation. The future of wind energy is extremely bright and there is no doubt that in the renewable energy sector, wind power would play a predominant role in adding to the national grids clean and non-polluting energy in the coming years (Table 4).

In recent years, demand for the micro wind turbines, of the output below 1 kW, is on the increase as monuments and educational materials. Most of the micro wind turbine that has a diameter under 1.0 m is low blade tip speed ratio type on the market, by the problem of the frequency, the safety and the blade noise. In these circumstances, it would be necessary to develop the system characteristics of micro wind turbines for the purpose of much higher performance in spite of the low Reynolds number regions. Wind power generation is characterised by its stochastic nature, whereby supply and demand, in small grid systems in particular, mostly do not match. The combination of wind power with a second complementary power generation and/or direct/indirect storage technology therefore has, in principle, considerable potential. Wind-diesel, wind-water desalination and wind power in combination with hydrogen production are all potential options that have been high on the international renewable energy agenda for several years. A small-scale wind-PV hybrid power generator system for dairy farm is shown in Figure 1, to verify the possibilities to apply a power generating system and heating source for dairy farm. It is possible to apply the system for power supply and heat source to melt snow and process fertiliser.

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Table 4
Installed capacity per year.

Year	Europe (MW)	World (MW)
Before 2000	9.413	13.954
2000	13.306	18.449
2001	17.812	24.927
2002	23.832	32.037
2003	29.301	40.301
2004	34.725	47.912
2005	40.897	59.320
2006	48.628	74.517
2007	57.136	94.593
2008	66.785	120.458
2009	78.514	151.753
2010	93.590	191.318

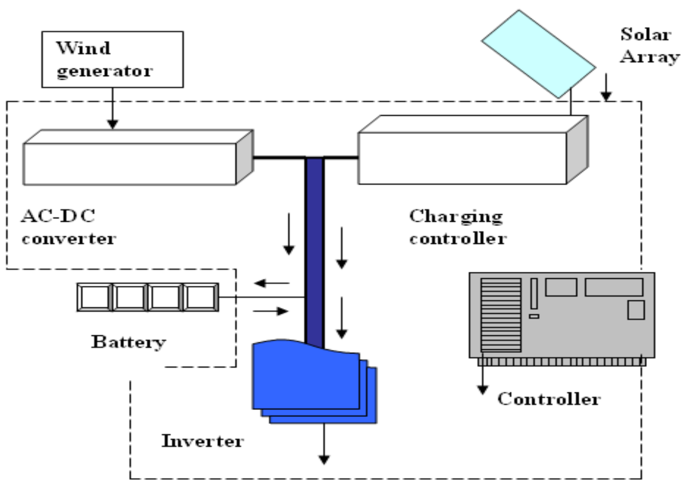

Fig. 1. Wind-Photovoltaic hybrid generation systems.

Many developing nations need to expand their power systems to meet the demand in rural areas. However, extending central power systems to remote locations is too costly an option in most cases. Then, autonomous small-scale energy systems can meet the electricity demand in remote locations, even though they generate relatively little power. However, even little electricity would contribute greatly to the quality of life in some places of developing countries. Being one of the most promising autonomous power technologies, wind energy applications, in the power range from tens of Watts (W) to kilowatts (kW), are increasingly growing in rural areas of developing countries.

Technical and economical aspects of the WESs should further be improved to sustain this growth. Techno-economically optimal designs are crucial for wind systems in competing with the conventional and more reliable power systems. High performance at the lowest possible cost will encourage the use of such systems and lead to more cost effective systems gradually (Figure 2). Design tools, allowing system performance assessment over a certain period of time, are therefore of great importance for sizing and optimisation purposes.

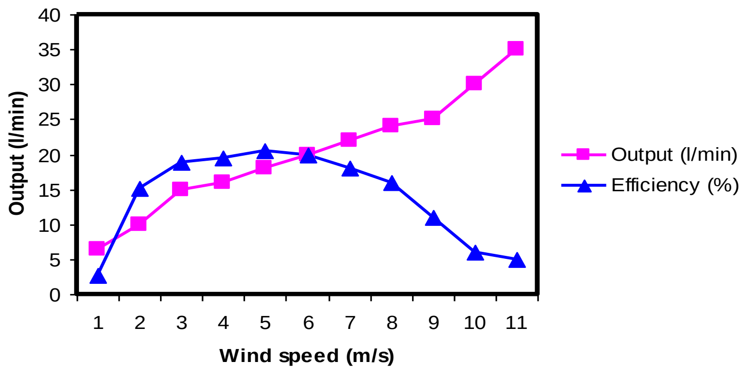

Fig. 2. Performance of the wind pump.

Wind power now accounts for the dominant share of global investment in renewable energy. Total wind power capacity grew by 28% worldwide in 2007 to reach an estimated 95 GW. Annual capacity additions by market size increased even more 40% higher in 2007 compared to 2006. Wind markets have also become geographically broad, with capacity in over 70 countries. Even as turbine prices remained high, due in part to materials costs and supply-chain troubles, the industry saw an increase in manufacturing facilities in the United States, India and China, broadening the manufacturing base away from Europe with the growth of more localised supply chains. India has been exporting components and turbines for many years and it appeared that 2006 and 2007 marked a turning point for China as well, with deals announced for the export of Chinese turbines and components. The annual energy yield is calculated by multiplying the wind turbine power curve with the wind distribution function at the site:

$$E_y = \sum_{i=1}^{i=n} f_{wi} P_{wi} \qquad (1)$$

where:
E_y is annual energy yield in kWh.
w is the wind speed in m/s.
n is the number of data bins converting the wind speed range of the turbine (0.5 or 1 m/s intervals).
f_{wi} is the number of hours per year for which wind speed is w m/s.
P_{wi} is the power resulting from a wind speed of w m/s.

Based on power curve from Figure 3 and the Weibull wind speed distribution, with a shape factor of 2, and the gross energy yield corresponding to 7-8.5 m/s is 10 MW.

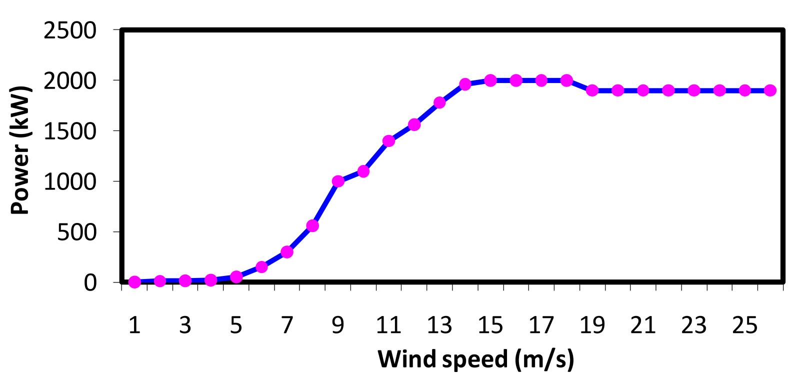

Fig. 3. A power/wind speed curve.

Unchanging for all wind turbines- big or small- is a number of crucial factors that together determine the annual energy-generating potential in kWh/m^2 of rotor swept area. Key factors that impact potential energy yield and their physical relationships are expressed in the formula:

$$P = ½ \rho C_p \eta_{me} \eta_{el} V^3 A \quad (2)$$

where:
P is the wind turbine power performance fed into the grid (Watts).
C_p is an aerodynamic efficiency of conversion of wind power into mechanical power, often called the power coefficient.
η_{me} is the conversion efficiency of mechanical power in the rotor axis into mechanical power in the generator axis. Encompasses all combined losses in the bearings, gearbox and so on.
η_{el} is the conversion efficiency of mechanical power into electric power fed into the grid, encompassing all combined losses in the generator, frequency converter, transformer, switches, etc.
ρ is the air density in kg/m^3 depends on environmental conditions.
V is the wind speed some three-rotor diameters upwind from the rotor plane in m/s.
A is the rotor swept area in m^2.

Each of the elements of the performance formula has its own distinct contribution to total wind turbine power output and resulting yearly energy yield. Traditionally wind turbines applied in an open field are horizontal-axis designs fitted with an upwind rotor. In the operational output range, wind power generated increases with wind speed cubed. Rotor swept area is a function of the rotor diameter squared and is the second key wind turbine output variable. The Boyle-Gay-Laussac Law shows the impact of temperature and pressure on density, whereby density is proportional to pressure divided by temperature. The influence of air density on wind turbine performance is therefore limited.

2.1. Analysis and assessment methodologies

Three basic methods have been used in wind energy resource assessments:

- Statistical and subjective analysis of existing wind measurements, other meteorological data and topographical information;
- Qualitative indicators of long-term wind speed levels; and
- Application of boundary layer similarity theory and the use of surface pressure observations.

In general, wind data in summarised or digitised formats are preferred. For stations having several different types of summarised wind data covering various time periods, one or two of the better summaries for those stations should be selected considering:

- The most suitable format for wind power assessment;
- The longest record;
- The least charge in anemometer evaluation and exposure; and
- The most frequent daily observations.

In many remote areas, wind data may be sparse or non-existent and evaluation of the wind data may have to rely on qualitative rather than quantitative methods. For example, there are topographic/meteorologic indicators of both high and low wind power classes. The following are some indicators of a potentially high wind power class:

- Gaps, passes and gorges in areas of frequent strong pressure gradients.
- Long valleys extending down from mountain ranges.
- Plains and plateaus at high evaluations.
- Plains and valleys with persistent down slope winds associated with strong pressure gradients.
- Exposed ridges and mountain summits in areas of strong upper-air winds.
- Exposed coastal sites in areas of strong upper-air winds or strong thermal pressure gradients.

Features generally indicative of low mean wind speeds are as follows:

- Valleys perpendicular to the prevailing wind a lot.
- Sheltered basins.
- Short and/or narrow valleys and canyons.
- Areas of high surface roughness (e.g., forested hilly terrain).

2.2. Statistical distribution for wind data

2.2.1. Methods of analysis

Available wind data from the Meteorological Department must be used. The data must be subsequently stratified according to quality, based on the following factors:

- Accuracy of the recording equipment and techniques.
- Type of data collected.
- Exposure of the recording equipment.
- Recording period (year).
- Recording rate/interval.

2.2.2. Adjustment of evaluation

Due to the anemometers at different meteorological stations being set at different levels, the measurements, prior to analysis, have to be adjusted to the same height. The standard height, according to the World Meteorological Organisation (WMO), is 10 meters above ground level (Baroudi et al., 2007). This height is adopted in the following analysis. There are two methods that can be used to adjust the wind velocity at one level to another level. One of them is the application of power law; the other is to employ the logarithmic law.

2.2.3. Power law

Power law is a mathematical relation representing measured wind speed profile in turbulent boundary layer. This relation is expressed in the form:

$$(V_1/V_2) = (h_1/h_2)^n \qquad (3)$$

Where V_1 is wind speed at height h_1 in turbulent boundary layer; V_2 is free stream wind speed; h_2 is boundary layer thickness; and n is power law exponent. Practically, the wind speed at any height Z is adjusted to the speed at Z reference. The equation, then, becomes:

$$(V_{ref}/V_Z) = (Z_{ref}/Z)^n \qquad (4)$$

or

$$V_{ref} = V_Z(Z_{ref}/Z)^n \qquad (5)$$

Power law exponent varies depending on the surface roughness. It has a value of 0.14 for calm sea, 0.4 for town (Omer, 1993). In 1978, Smedman-Högström and Högström (WMO, 1994) proposed a relationship between the exponent n and the surface roughness Z_o. Their proposed relation, deduced from the experimental results, also includes the stability of the atmosphere. This relationship can be mathematically written as:

$$n = C_o + C_1 \log Z_o + C_2 \log Z_o \qquad (6)$$

Where C_o, C_1 and C_2 vary with the stability of the atmosphere, Z_o is the surface roughness length, which is shown in Tables (5) and (6).

Table 5
Roughness of height for different types of terrain.

Terrain	Types	Roughness height Z_o (m)
Flat	Ocean, landscape and beach	0.005
Open	Low grass, airports, high grass and low crops	0.03
Rough	Tall row crops	0.25
Very rough	Forests	0.50
Closed	Villages	1.00
Towns	Town centre and open spaces in forests	>2.0

Table 6
Values of the constants C_o, C_1 and C_2 of the equation (4) for n as a function of log Z_o

Stability class	C_o	C_1	C_2
1, 2 Unstable	0.18	0.13	0.03
3 Near neutral	0.30	0.17	0.03
4 Slightly stable	0.52	0.20	0.03
5 Stable	0.80	0.25	0.03
6 Very stable	1.03	0.31	0.03

A number of effects have to be considered:

(1) Wind shear: The wind slows down, near the ground, to an extent determined by the surface roughness.
(2) Turbulence: Behind buildings, trees, ridges, etc.
(3) Acceleration: (Or retardation) on the top of hills, ridges, etc.

Wind flowing around buildings or over very rough surfaces exhibits rapid changes in speed and/or direction, called turbulence. This turbulence decreases the power output of the wind machine and can also lead to unwanted vibrations of the machine. Generally, the effect is stronger when the ridge is rather smooth and not too steep nor too flat. The orientation of the ridge should preferably by perpendicular to the prevailing wind direction. If the ridge is curved, it is best if the wind blows in the concave side of the ridge. A quantative indication of acceleration is difficult to give, but increases of 10% to 20% in wind speed are easily attained. Isolated hills give less acceleration than ridges, because the air tends to flow around the hill. This means that in some cases the two hillsides, perpendicular to the prevailing wind, are better locations than top.

The power output of wind rotor increases with the cube of the wind speed. This means that the site for a wind machine must be chosen very carefully to ensure that the location with highest wind speed in the area is selected. The site selection is rather easy in flat terrain but much more complicated in hilly or mountainous terrains. The manipulations are meant to facilitate the judgement to what extent a given location might be suitable for the utilisation of wind energy. In this respect, interest in the following:

- The daily, monthly and annual wind pattern.
- The duration of low wind speeds and high wind speeds.
- The expected locations must be not too far from the place of measurements.
- The maximum gust speed.
- The wind energy produced per month and per year.

2.2.4. Logarithmic law

Logarithmic law is the equation using physical arguments and experiment in analysis. This equation is:

$$(V_Z/V_*) = 1/k \ln (Z/Z_o) \quad (7)$$

Where V_* is friction velocity; V_Z is the wind speed at height Z; k is Von Karman constant, equals to 0.4; Z_o is the surface roughness length which can be found from (Eldridge, 1980). Monin and Obukov (Smedman-Högström, and Högström, 1978) modified equation (7) by including the stability of the atmosphere. Their modified equation becomes:

$$V_Z = V_*/k [\ln Z/Z_o - \Phi(Z/L)] \quad (8)$$

Where $\Phi(Z/L)$ is a function with value varying with the stability of the atmosphere. For examples:
Stable condition:

$$\Phi(Z/L) = -4.7 Z/L \quad (9)$$

where ($1/L > 0.003$ m^{-1})

Neutral condition:

$$\Phi(Z/L) = 0 \quad (10)$$

Where ($-0.003 < 1/L \leq 0.003$ m^{-1})

Unstable condition:

The determination of k and c was made in two steps (Wong, 1977) (ESDU 72026, 1972). In the first step, the initial values are estimated by the moment method. In the second step, the maximum likelihood estimation is used to calculate the Weibull parameters (k and c are of course the solutions of the following system:

$$\delta \text{ Ln } L/\delta k = 0, \ \delta \text{ Ln } L/\delta c = 0$$

$$LnL = N.Ln(k) - N.k.Lnc + (k-1)\sum_{i=1}^{N} Ln(vi) - \sum_{i=1}^{N}\left(\frac{vi}{c}\right)^{k} \quad (11)$$

Where N is a set of an hourly data.

Determination of the position on the earth surface for evaluating the surface roughness: Equation (7) requires the value of surface roughness. However, in order to get the value of surface roughness, it is necessary to fix the area that has an influence on wind profile at the level to be adjusted. Smedman-Högström and Högström (WMO, 1994) derived the relationship between the growth of the internal boundary layer, Z_X and the distance from the discontinuity, X from the analysis of Pasquill (Monin and Obukov, 1954):

$$Z_X = aX^b \quad (12)$$

In which a and b are constants which vary with stability and surface roughness.

2.2.5. Available wind energy

The power available (P_a) in cross sectional area A perpendicular to the wind stream moving at speed V is:

$$P_a = 0.5 \rho A V^3 \quad (13)$$

where ρ is the air density.

Sometime available wind energy is expressed as power density:

$$P_a/A = 0.5 \rho V^3 \quad (14)$$

However, wind machines can utilise not all of this power. The amount of power, which can be extracted from the wind stream, depends on the available wind energy and on the operating characteristics of the wind energy extraction device. The power output P of a wind energy conversion system, which subtends area A of the wind speed V, and density ρ is:

$$P = 0.5\ \eta\ C_p\ \rho\ A\ V^3 \quad (15)$$

Where η is the power coefficient (is the ratio of the actual output compared to the theoretical available = Actual power/theoretical power) (Wong, 1977), $C_{p\ (Betz)}$ = 16/27 = (0.593) is the theoretical maximum efficiency of the Betz Limit (in other words, theoretical maximum fraction of extracted power). This maximum is called the Betz-maximum in honour of the wind pioneer who first derived its value (Pasquill, 1972) (Appendix 1), ρ is the air density (kg m^{-3}); the density of the air depends on the temperature and on the altitude above sea level.

2.2.6. Weibull distribution

In recent years much efforts has been made to construct an adequate statistical model for describing the wind frequency distribution. Most attention has been focused on Weibull function, since this give a good fit to the experimental data (Lysen, 1983). Weibull distribution is characterised by two parameters: shape parameter, K and scale parameter, C. The probability density function is given by:

$$F(V)=(K/C)(V/C)^{K-1} \exp.[-(V/C)^K] \quad (16)$$

where V is the wind speed, K is the shape parameter and C is the scale parameter. In addition, the cumulative distribution functions by:

$$F(V) = \exp.[-(V/C)^K] \quad (17)$$

Where V is the wind speed.

The mean of the distribution, i.e., the mean wind speed, V is equal to:

$$V = C\ \Gamma\ (1/K+1) \quad (18)$$

where Γ is the gamma function.

Defining a reduced wind speed,

$$X = v/V \quad (19)$$

Where v is the average wind speed, and V is an accumulative wind speed parameter. The probability density function can be rewritten as:

$$F(X) = K\ \Gamma^K\ (1+1/K)\ X^{K-1} \exp.[-\Gamma^K\ (1+1/K)\ X^K] \quad (20)$$

Moreover, the cumulative distribution functions as:

$$F(X) = 1-\exp.[-\Gamma^K\ (1+1/K)\ X^K] \quad (21)$$

There are several methods for determining the Weibull distribution parameters, for example, the method of moment, the method using the energy pattern factor, the method of maximum likelihood and the method of least square fit of the cumulative probabilities (Pasquill, 1972; Lysen, 1983).

Wind is simple air in motion. It is caused by the uneven heating of the earth’s surface by the sun. Since the earth’s surface is made of very different types of land and water, it absorbs the sun’s heat at different rates. Today, wind energy is mainly used to generate electricity. Wind energy is also world's fastest growing energy source and is a clean and renewable source that has been in use for centuries in Europe and more recently in the United States and other nations. Wind turbines, both large and small, produce electricity for utilities and homeowners and remote villages. Wind energy is a clean energy source as electricity generated by wind turbines do not pollute the air or emit pollutants like other energy sources. This means less smog, less acid rain and fewer greenhouse gas emissions (GHGs). Every 10,000 MW of wind installed can reduce CO_2 emissions by approximately 33 MMT annually if it replaces coal-fired generating capacity, or 21 MMT if it replaces generation from average fuel mix. Many developing countries have little incentive to use wind energy technologies, to reduce their emissions despite the fact that the most rapid growth in CO_2 emissions is in the developing world.

Two related activities could give both developed and developing countries incentives to develop wind projects. The first is joint implementation, a programme under which firms from the developed countries can earn carbon offsets by building clean energy projects in the developing world. Developed nations should endorse and push for joint implementation to move from its current status to full-scale implementation. The second activity is the World Bank's Global Environmental Facility (GEF), which can cover the incremental cost of developing environmentally benign or beneficial projects in the developing world, such as building a wind projects instead of an apparently cheaper coal projects. This incentive is particularly important for countries such as China and India, which have tremendous power needs and must build energy capacity quickly at the lowest possible cost. Without going into details, the materials can be ranked in terms of decreasing cost, e.g., titanium, aluminium, plastics (on average), iron and cement (Stevens and Smulders, 1979; Rodda, 2001).

Wind energy technology and applications:

- Small, micro-generation and hybrid systems.
- Machines and wind farms.
- Offshore wind power.
- Wind resources and environmental issues.
- Connection and integration.
- National and regional programmes.
- Economic and institutional issues.

The following are concluded:

- Promoting innovation and efficient use of applicable wind energy technologies.
- Identifying the most feasible and cost effective applications of wind energy resources suitable for use.
- Highlighting the local, regional and global environmental benefits of wind energy applications.
- Ensuring the wind energy takes its proper place in the sustainable developments, supply and use of energy for greatest benefit of all, taking due account of research requirements, energy efficiency, conservation and cost criteria.
- Ensuring the financing of and institutional support for economic wind energy projects.
- Encouraging education, research and training in wind energy technology in the region.

3. Problems and difficulties in rural energy development

The following problems are summarised:

3.1. Imbalance in rural energy development

Due to the difference in economic conditions in different areas, the development of rural energy is considerably imbalanced. The main challenge to energy policymakers in the 21st century is how to develop and manage adequate, affordable and reliable energy services in a sustainable manner to fuel social and economic development. Generally, future rural energy will be oriented towards green energy, and the future development of rural energy will concentrate on biogas, small hydropower, solar energy, and wind power.

3.2. Insufficient investment in development of rural energy

Current rural energy relies mainly on charcoal, firewood and green energies, such as electricity and biogas. The bad economic situation leads to considerable difficulty in the development of rural energy, and farmers in remote areas still prefer ‘‘free firewood’’ for their cooking due to their low income. Hence, further development of rural energy needs significant financial support from the government at various levels. Although the work of rebuilding traditional stoves has been almost finished, most of the rebuilt fuel-saving stoves have a thermal efficiency less than 20%.

3.3. Excessive dependence on forests for rural energy

Currently, energy for rural household use comes mainly from burning of firewood. The annual consumption of forests is 1.96×10^6 m^3, and of this 0.65×10^6 m^3 is as firewood. To some extent, this pattern of energy consumption has led to environmental damage such as water and soil loss, decrease in forest cover, and air pollution. The excessive use of firewood from forests for rural energy would cause damage to sightseeing resorts, make animals lose their habitats, and lead to the extinction of some endangered plants. The future development of rural energy should be aimed at completely changing the current pattern of energy consumption, fully utilising abundant resources of hydropower, biomass, solar and wind energy, promoting economic growth through the development of rural energy and integrated utilisation of biomass.

4. Conclusion

We love in a society of unprecedented: consumption is the norm. Nevertheless, people are only just starting to be concerned about the process that gets products onto the shelves and the effect of their use on our planet. The massive increases in fuel prices over the last years have however, made any scheme not requiring fuel appear to be more attractive and to be worth reinvestigation. Economic projections are difficult at the best of times, when economies are relatively stable and a reference ‘business as usual’ case can be used. However, there are numerous signals that the world faces very turbulent economic conditions for a while -a credit crunch may make some project finance difficult and the shortage of raw materials could lead to supply chain difficulties. However, the rapidly escalating price of oil is focusing a lot of attention on the price of energy and the hedge of electricity supply without a fuel cost is likely to become increasingly attractive to many companies and utilities. At some stage, rising fuel costs could lead to demand for wind energy becoming almost infinite. The main factors expected to influence the continuing growth of the energy sector are:

- The economies of the transition states (Russia and Central Asia) will start to grow.
- Increasing energy demand in Asia and South America.
- Oil prices will continue to remain high as will demand for fossil fuels.
- Continuing competitiveness of renewables with fossil fuels.
- Many countries may find they are well off their international CO_2 reduction commitments and need to install some new renewable capacity very quickly.
- Security of supply questions will continue to support renewable technologies.
- Deregulated markets will remove excess conventional power capacity and new capacity is likely to be more expensive than wind.

Newspapers, TV, schools, universities and politicians rant and rave about being ‘green’ and doing our bit for the environment, but can we as individuals change things? Energy efficiency brings health, productivity, safety, comfort and savings to homeowner, as well as local and global environmental benefits. The use of renewable energy resources could play an important role in this context, especially with regard to responsible and sustainable development. It represents an excellent opportunity to offer a higher standard of living to local people and will save local and regional resources. Implementation of greenhouses offers a chance for maintenance and repair services. It is expected that the pace of implementation will increase and the quality of work to improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is important and more transparent. Various passive techniques have been put in perspective, and energy saving passive strategies can be seen to reduce interior temperature increase thermal comfort, and reducing air conditioning loads. The scheme can also be employed to analyse the marginal contribution of each specific passive measure working under realistic conditions in combination with the other housing elements. In regions where heating is important during winter months, the use of top-light solar passive strategies for spaces without an equator-facing façade can efficiently reduce energy consumption for heating, lighting and ventilation.

The current analysis does support the below-mentioned recommendations, which are also drawn from the author own experience. However, further research is needed to find out if such recommendations might be effective:

- Launching of public awareness campaigns among local investors particularly small-scale entrepreneurs and end users of renewable energy technology (RET) to highlight the importance and benefits of renewable, particularly solar and wind energy resources.
- Amendment of the encouragement of investment act, to include furthers concessions, facilities, tax holidays and preferential treatment to attract national and foreign capital investment.
- Allocation of a specific percentage of soft loans and grants obtained by governments to augment budgets of research and development (R and D) related to manufacturing and commercialisation of RET.

- Governments should give incentives to encourage the household sector to use solar and wind energy instead of conventional energy.
- Execute joint investments between the private-sector and the financing entities to disseminate the renewable with technical support from the research and development entities.
- Availing of training opportunities to personnel at different levels in donor countries and other developing countries to make use of their wide experience in application and commercialisation of RET particularly solar and wind energy devices.
- The governments should play a leading role in adopting solar and wind energy devices in public institutions, e.g., schools, hospitals, government departments, police stations etc., for lighting, water pumping, water heating, communication and refrigeration.
- To encourage the private-sector to assemble, installs, repair and manufacture solar and wind energy devices via investment encouragement, more flexible licensing procedures.

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