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Evaluation of Solar and Wind Energy Resources

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Abstract

Renewable energy resources (solar, wind and biomass) is one of the most fundamental of natural resources that Sudan must harness in its efforts for rapid economic development. The role of renewable energy technologies in the development process cannot be over – emphasised. The demand for energy in Sudan has increased tremendously over the years and will continue to increase in view of the accelerating pace of population growth, urbanisation and industrialisation. Comprehensive renewable energy resources management is a necessity. Human resource development should be based on education and training programmes funded both by the private and public sector. Promotion research and development, demonstration and adaptation of energy resources amongst national, regional, and international organisations which seek clean, pure, safe, and abundant energy sources. Results, suggest that, wind pumps, solar stills, and biogas energy must be encouraged, invested, and implemented, but especially for remote rural areas of Sudan.

Keywords

Renewable Technologies; Solar Energy; Wind Energy; Biomass Energy; Sudan; Environment

1. Introduction

Sudan has a population of about 26 million with an annual growth rate of 2.8 % with a population density of less than 10 per square kilometres. In the last two decades, Sudan has been suffering from an imbalance of trade. This has led to serious energy problems and environmental destruction.

Energy supply in Sudan is about 11.7 million tons of oil equivalents (TOE). Out of this only 57 % reached the end users due to conversion losses. About 87 % of this energy supply is biomass [1]. Petroleum energy supply represented only 12% of the total energy supply. Electricity supply represented almost 1 % of the total energy (hydropower supplies 58%, and the rest is supplied by thermal and gas turbines). As Sudan is a tropical country with high solar radiation and moderate wind, solar and wind energies seem to be attractive sources of energy. In Sudan, great attention is given to renewable energy utilisation since the country has potential for this.

This communication presents a review of three projects carried by national company for manufacturing water equipment limited (NCMWE). Wind pumps (two are locally manufactured, installed and tested), solar stills, and biogas technology. The future efforts must be toward the use of renewable environmentally – friendly, and appropriate technologies in Sudan.

With increasing urbanisation in the world, cities are growing in number, population and complexity. At present, 2 % of the world's land surface is covered by cities, yet the people living in them consume 75 % of the

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resources consumed by mankind [2]. Indeed, the ecological footprint of cities is many times larger than the areas they physically occupy.

Economic and social imperatives often dictate that cities must become more concentrated, making it necessary to increase the density to accommodate the people, to reduce the cost of public services, and to achieve required social cohesiveness. The reality of modern urbanisation inevitably leads to higher densities than in traditional settlements and this trend is particularly notable in developing countries.

Today, the challenge before many cities is to support large numbers of people while limiting their impact on the natural environment. Buildings are significant users of energy and materials in a modern society and, hence, energy conservation in buildings plays an important role in urban environmental sustainability. A challenging task of architects and other building professionals, therefore, is to design and promote low energy buildings in a cost effective and environmentally responsive way. Passive and low energy architecture has been proposed and investigated in different locations of the world [3, 4]; design guides and handbooks were produced for promoting energy efficient buildings [5-8]. However, at present, little information is available for studying low energy building design in densely populated areas. Designing low energy buildings in high-density areas requires special treatment to the planning of urban structure, co-ordination of energy systems, integration of architectural elements, and utilisation of space. At the same time, the study of low energy buildings will lead to a better understanding of the environmental conditions and improved design practices. This may help people study and improve the quality of built environment and living conditions.

However, the term low energy is often not uniquely defined in many demonstration projects and studies [9]. It may mean achieving zero energy requirements for a house or reduced energy consumption in an office building. A major goal of low energy building projects and studies usually is to minimise the amount of external purchased energy such as electricity and fuel gas. Yet, sometimes the target may focus on the energy costs or a particular form of energy input to the building. As building design needs to consider requirements and constraints, such as architectural functions, indoor environmental conditions, and economic effectiveness, a pragmatic goal of low energy building is also to achieve the highest energy efficiency, which requires the lowest possible need for energy within the economic limits of reason. Since many complicated factors and phenomena influence energy consumption in buildings, it is not easy to define low energy building precisely and to measure and compare the levels of building energy performance. The loose fit between form and performance in architectural design also makes quantitative analysis of building energy use more difficult. Nevertheless, it is believed that super-efficient buildings, which have significantly lower energy consumption, can be achieved through good design practices and effective use of energy efficient technology [10].

In an ideal case, buildings can even act as producers rather than consumers of energy. Besides the operational energy requirements of buildings, it is important to consider two related energy issues. The first one is the transport energy requirements as a result of the building and urban design patterns and the second one is the embodied energy or energy content of the building materials, equipment or systems being used. Transport energy is affected by the spatial planning of the built environment, transport policies and systems, and other social and economic factors. It is not always possible to study the effect of urban and building design on transport energy without considering the context of other influencing factors. The general efficiency rules are to promote spatial planning and development, which reduce the need to travel, and to devise and enforce land-use patterns that are conducive to public transport [11]. Embodied energy, on the other hand, is the energy input required to quarry, transport and manufacture building materials, plus the energy used in the construction process. It represents the total life-cycle energy use of the building materials or systems and can be used to help determine design decisions on system or materials selection [12]. At present, the field of embodied energy analysis is generally still only of academic interest and it is difficult to obtain reliable data for embodied energy. Research findings in some countries indicate that the operating energy often represents the largest component of life-cycle energy use. Therefore, most people, when studying low energy buildings, would prefer to focus on operating energy, and perhaps carry out a general assessment of embodied energy only.

To handle population growth on a limited land basis, the word density is unavoidable. Instead of expanding the boundary, cities often respond to development pressure by setting targets for increased urban densities. This, however, results in the establishment of a high-rise cityscape and compact urban settings. The effects of urban concentrated load centres and compactness of land use patterns will bring benefits to energy distribution and transport system design, but crowded conditions may create congestion and undesirable local microclimate. Burchell and Listokin [13] have discussed the urban energy advantage and believed that cities are more energy efficient for the following reasons:

1. The urban building stock, due its density and compactness, consumes less energy.

2. Cities benefit from advantageous transportation and commutation characteristics.

3. Cities can easily capitalise from emerging more efficient energy systems, and

4. High densities and mixing of land uses may contribute to better efficiency.

1.1 Methodology

The increased availability of reliable and efficient energy services stimulates new development alternatives. This communication discusses the potential for such integrated systems in the stationary and portable power market in response to the critical need for a cleaner energy technology. Anticipated patterns of future energy use and consequent environmental impacts (acid precipitation, ozone depletion and the greenhouse effect or global warming) are comprehensively discussed in this study. Throughout the theme several issues relating to renewable energies, environment, and sustainable development are examined from both current and future perspectives. It is concluded that green energies like wind, solar, ground-source heat pumps, and biomass must be promoted, implemented, and demonstrated from the economic and/or environmental point view. This article sheds light on the possibilities of utilizing wind energy in Sudan, and focuses on the viability of manufacturing wind pumps locally. The work is limited to few locations/sites in the country, and results of one reliable site (Soba) have been included in the discussion. Also, the work was limited to one make/type of wind pumps (CWD 5000), but reflections on other makes (Kijito) have been considered. Wind energy for water pumping was the main aim; no other use was included in the research.

2. Renewable Energy Technologies

The increased exploitation of renewable energy sources is central to any move towards sustainable development. However, casting renewable energy thus carries with it an inherent commitment to other basic tenets of sustainability, openness, democraticisations, etc. Due to increasing fossil fuel prices, the research in renewable energy technologies (RETs) utilisation has picked up a considerable momentum in the world. The present day energy arises has therefore resulted in the search for alternative energy resources in order to cope with the drastically changing energy picture of the world. The environmental sustainability of the current global energy systems is under serious question. A major transition away from fossil fuels to one based on energy efficiency and renewable energy is required. Alternatively energy sources can potentially help fulfil the acute energy demand and sustain economic growth in many regions of the world. The mitigation strategy of the country should be based primarily ongoing governmental programmes, which have originally been launched for other purposes, but may contribute to a relevant reduction of greenhouse gas emissions (energy-saving and afforestation programmes). Throughout the study several issues relating to renewable energies, environment and sustainable development are examined from both current and future perspectives. The exploitation of the energetic potential (solar and wind) for the production of electricity prove to be an adequate solution in isolated regions where the extension of the grid network would be a financial constraint.

The provision of good indoor environmental quality while achieving energy and cost efficient operation of the heating, ventilating and air-conditioning (HVAC) plants in buildings represents a multi variant problem. The comfort of building occupants is dependent on many environmental parameters including air speed, temperature, relative humidity and quality in addition to lighting and noise. The overall objective is to provide a high level of building performance (BP), which can be defined as indoor environmental quality (IEQ), energy efficiency (EE) and cost efficiency (CE).

• Indoor environmental quality is the perceived condition of comfort that building occupants experience due to the physical and psychological conditions to which they are exposed by their surroundings. The main physical parameters affecting IEQ are air speed, temperature, relative humidity and quality.

• Energy efficiency is related to the provision of the desired environmental conditions while consuming the minimal quantity of energy.

• Cost efficiency is the financial expenditure on energy relative to the level of environmental comfort and productivity that the building occupants attained. The overall cost efficiency can be improved by improving the indoor environmental quality and the energy efficiency of a building.

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 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 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 Gig watts. 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 deployment of offshore wind power can be considered to have happened in two phases to date. The first phase involved a series of small demonstration projects generally constructed in sheltered shallow waters from 1995 to 2000. The second phase was for projects, which still had a demonstration role, but which were of an increasingly commercial nature and were developed in more technically demanding situations between 2000 and 2004. In the year 2000, seven mostly small-scale demonstration projects were operational. By 2004, the industry had developed 15 projects many of them large-scale and fully commercial.

2.1 Wind Energy

Forty years ago, wind pumps were very common in central Sudan. Unfortunately, they disappeared gradually due to scarce spare parts, lack of maintenance skills as well as stiff competition from relatively cheap diesel pumps. The government reintroduced wind pumps to counter the high prices of imported diesel fuel and the difficulties in transporting it to remote areas.

In 1985, the energy research institute (ERI) in cooperation with a consultancy services firm started a wind pumps project. The project was financed by the Netherlands ministry of foreign affairs [14]. During the 14 months of the project life, ten imported wind pumps were installed in Khartoum area, while one was locally manufactured for demonstration. Results suggested that wind energy would be more profitably used for local applications in Sudan. After the termination of the project, the ERI continued monitoring and testing the performance of the installed pumps.

For wind pumps to be effective, it is recommended that more research should be carried out on adapting the design to the materials available in the local market, quality control guidelines ought to be set up and users should be trained on how to utilise the pumps more efficiently.

The consultancy firm set out to produce wind pumps for low head pumping applications which could be built in developing countries. The wind pump produced consists of an eight – bladed rotor which is directly coupled to a specially designed piston pump. This pump is fabricated with a small leak – hole (to facilitate starting) and a continuous replenished air chamber (served by a small air pump driven by a wind machine). The design is relatively simple and is within the capabilities of the local manufacturers. So far, two wind pumps have been manufactured locally at a cost of us $ 2500 each. The test results show that the design has some deficiencies. The wind pump's performance is about 50% of that predicted by the firm. This could be due to low pump efficiency and high start – up wind speed (3 ms^{-1}). The frequency of maintenance required is high (at least once every two months).

2.2 Solar Energy

Sudan enjoys bright sunshine and dry weather most of the year. It receives 10 to 12 hours of sunshine per day with a high level of radiation. The solar radiation is abundant and can contribute to the country's energy use if suitable and appropriate technologies are introduced.

Solar energy can be utilised directly for water desalination or water heating. Due to the rise in the prices of conventional fuels, solar desalination is more promising and cheaper to use. It offers an attractive alternative as it is hygienic and helps to reduce the consumption of fuel wood. Fortunately the areas which lack potable water supplies have abundant solar and wind energies.

Solar desalination was initiated in Sudan as a possible answer for converting the underground brackish water into potable water to contribute to the anti – thirst campaign especially at those isolated arid areas lacking both fresh water and power.

Solar stills are used for distilling the water. A solar still unit consists of a basin, insulating bottom layer, black lining, transparent cover arranged in such a way that the surface slope downwards and rests on a collecting trough at the sides. The design is simple in construction, operation, and maintenance; rigid and firm enough to resist the worst prevailing environmental conditions; and attempts to use locally available materials (essential foreign materials are minimised to the least). The energy research institute (ERI) set up a bilateral project in conjunction with the national company for manufacturing water equipment limited (NCMWE) in February, 1995.

This project aims at solving the salinity problem in isolated areas. It has been under – taking research with a view to developing a solar still design that is economical and technically suitable for use in Sudan. It has also carried out tests on the performance of existing solar stills under varying prevailing operational conditions.

The parameters that affect the average productivity of the solar stills include: solar radiation, ambient temperature, wind velocity, depth of the brine in the basin, cover material and its shape, and construction; and insulating materials used (the life span of a still is 5 – 10 years).

Tests were done in ‘‘kilo eight area’’ of Khartoum and showed that the average productivity of a solar still is about one gallon per square meter per day. The daily productivity of solar stills is only slightly affected by dust, clouds, and cold weather. Solar stills are suitable for use in laboratories, medical purposes, charging and topping batteries, supplying drinking water to small communities in isolated sunny areas as well as local markets.

2.3 Biogas Energy

Many countries with agriculturally based economics face the growing problem of human, animal and plant waste. This waste is on one hand a very dangerous and continuous source of pollution, but is on the other hand a very useful source of energy.

A very common technique that utilises such waste is anaerobic fermentation, also called anaerobic digestion. The gas produced by the digestion of organic waste is known as biogas. It is colourless, flammable, and generally contains 50 – 70% methane (CH_4) and 30 – 40 % carbon dioxide (CO_2), with small amounts of other gases such as Hydrogen (H_2), Nitrogen (N_2), and Hydrogen Sulphide (H_2S). Its energy is more than (20,000 kJm^{-3}).

Among the many uses of biogas are water heating, space heating, lighting and cooking. Conversion of internal combustion engines to run on biogas can be relatively simple; thus the gas can also be used for pumping water and small – scale electric power generation. From the point of view of better thermal energy utilisation, it is more economical and convenient to use biogas to generate electricity for lighting, than to burn the biogas directly in biogas lamps.

In rural areas, it is very practical to change a small internal combustion engine with an asynchronous generator. This has many advantages such as simple structure, ease of operation and maintenance, less trouble, more safety and low installation cost. It is suitable for farms whose inhabitants are not too widely scattered. But such an engine – generator is usually regarded as unsuitable to supply a wider area on account of its low efficiency. Moreover, the digester can produce not only an excellent gas fuel but also a large quantity of digested sludge which is an excellent pollution – free organic fertiliser. Thus the promotion and development of agricultural and animal husbandry in rural areas can be optimised by coordination of biogas, fertiliser and pollution control.

3. Effects of Urban Density

As the quality of living and built environments has become a critical issue in many urban areas, it is useful to investigate low energy design and evaluate it against the social and environmental objectives. From psychological and sociological points of view, high population density and the effect of crowding are interesting topics, which have attracted much attention. A crowded and stressful urban environment may have unhealthy effects on the occupants due to air pollution and noise problems. On the other hand, the level of mobility and traffic speed will benefit the working and living of the people. Therefore, it should be noted that density and crowding are not necessarily found together. People who live under crowded conditions may not suffer from being crowded if the built environment has been designed to provide enough personal space and functional open space.

Compact development patterns can reduce infrastructure demands and the need to travel by car. As population density increases, transportation options multiply and dependence areas, per capita fuel consumption is much lower in densely populated areas because people drive so much less. Few roads and commercially viable public transport are the major merits. On the other hand, urban density is a major factor that determines the urban ventilation conditions, as well as the urban temperature [15]. Under given circumstances, an urban area with a high density of buildings can experience poor ventilation and strong heat island effect. In warm-humid regions these features would lead to a high level of thermal stress of the inhabitants and increased use of energy in air-conditioned buildings.

Table 1 gives a summary of the positive and negative effects of urban density. All in all, denser city models require more careful design in order to maximise energy efficiency and satisfy other social and development requirements. Low energy design should not be considered in isolation, and in fact, it is a measure, which should work in harmony with other environmental objectives. Hence, building energy study provides opportunities not only for identifying energy and cost savings, but also for examining indoor and outdoor environment.

Table 1: Effects of Urban Density on City's Energy Demand

Positive effects	**Negative effects**
Transport: Promote public transport and reduce the need for, and length of, trips by private cars.	Transport: Congestion in urban areas reduces fuel efficiency of vehicles.
Infrastructure: Reduce street length needed to accommodate a given number of inhabitants. Shorten the length of infrastructure facilities such as water supply and sewage lines, reducing the energy needed for pumping.	Vertical transportation: High-rise buildings involve lifts, thus increasing the need for electricity for the vertical transportation.
Thermal performance: Multi-story, multiunit buildings could reduce the overall area of the building's envelope and heat loss from the buildings. Shading among buildings could reduce solar exposure of buildings during the summer period.	Ventilation: A concentration of high-rise and large buildings may impede the urban ventilation conditions.
Natural lighting:	Urban heat island: Heat released and trapped in the urban areas may increase the need for air conditioning. The potential for natural lighting is generally reduced in high-density areas, increasing the need for electric lighting and the load on air conditioning to remove the heat resulting from the electric lighting.
Energy systems: District cooling and heating system, which is usually more energy efficiency, is more feasible as density is higher.	Use of solar energy: Roof and exposed areas for collection of solar energy are limited.
Ventilation: A desirable in flow pattern around buildings may be obtained by proper arrangement of high-rise building blocks.	

However, it is also possible that a high-density urban area, obtained by a mixture of high and low buildings, could have better ventilation conditions than an area with lower density but with buildings of the same height. Closely spaced or high-rise buildings are also affected by the use of natural lighting, natural ventilation and solar energy. If not properly planned, energy for electric lighting and mechanical cooling/ventilation may be increased and application of solar energy systems will be greatly limited.

3.1 Energy Saving in Buildings

The admission of daylight into buildings alone does not guarantee that the design will be energy efficient in terms of lighting. In fact, the design for increased daylight can often raise concerns relating to visual comfort (glare) and thermal comfort (increased solar gain in the summer and heat losses in the winter from larger apertures). Such issues will clearly need to be addressed in the design of the window openings, blinds, shading devices, heating system, etc. In order for a building to benefit from daylight energy terms, it is a prerequisite that lights are switched off when sufficient daylight is available. The nature of the switching regime; manual or automated, centralised or local, switched, stepped or dimmed, will determine the energy performance. Simple techniques can be implemented to increase the probability that lights are switched off [16]. These include:

• Making switches conspicuous.

• Loading switches appropriately in relation to the lights.

• Switching banks of lights independently.

• Switching banks of lights parallel to the main window wall.

There are also a number of methods, which help reduce the lighting energy use, which, in turn, relate to the type of occupancy pattern of the building [16]. The light switching options include:

• Centralised timed off (or stepped)/manual on.

• Photoelectric off (or stepped)/manual on.

• Photoelectric and on (or stepped), photoelectric dimming.

• Occupant sensor (stepped) on/off (movement or noise sensor).

Likewise, energy savings from the avoidance of air conditioning can be very substantial. Whilst day-lighting strategies need to be integrated with artificial lighting systems in order to become beneficial in terms of energy use, reductions in overall energy consumption levels by employment of a sustained programme of energy consumption strategies and measures would have considerable benefits within the buildings sector. The perception is often given however is that rigorous energy conservation as an end in itself imposes a style on building design resulting in a restricted aesthetic solution. Better perhaps would be to support a climate sensitive design approach which encompassed some elements of the pure conservation strategy together with strategies which work with the local ambient conditions making use of energy technology systems, such as solar energy, where feasible. In practice, low energy environments are achieved through a combination of measures that include:

• The application of environmental regulations and policy.

• The application of environmental science and best practice.

• Mathematical modelling and simulation.

• Environmental design and engineering.

• Construction and commissioning.

• Management and modifications of environments in use.

While the overriding intention of passive solar energy design is to achieve a reduction in purchased energy consumption, the attainment of significant savings is in doubt. The non-realisation of potential energy benefits is mainly due to the neglect of the consideration of post-occupancy user and management behaviour by energy scientists and designers alike. Buildings consume energy mainly for cooling, heating and lighting as shown in Table 2. The energy consumption shown in the table was based on the assumption that the building operates within ASHRAE-thermal comfort zone during the cooling and heating periods [17]. Most of the buildings incorporate energy efficient passive cooling, solar control, photovoltaic, lighting and day lighting, and integrated energy systems. It is well known that thermal mass with night ventilation can reduce the maximum indoor temperature in buildings in summer [18]. Hence, comfort temperatures may be achieved by proper application of passive cooling systems. However, energy can also be saved if an air conditioning unit is used [19]. The reason for this is that in summer, heavy external walls delay the heat transfer from the outside into the inside spaces.

Moreover, if the building has a lot of internal mass the increase in the air temperature is slow. This is because the penetrating heat raises the air temperature as well as the temperature of the heavy thermal mass. The result is a slow heating of the building in summer as the maximal inside temperature is reached only during the late hours when the outside air temperature is already low. The heat flowing from the inside heavy walls can be removed with good ventilation in the evening and night. The capacity to store energy also helps in winter, since energy can be stored in walls from one sunny winter day to the next cloudy one.

Table 2: Energy-Saving in Buildings

Passive Comfort Measures	Active Comfort Measures	Climatic Zones			
		Mediterranean	Subtropical	Tropical	Desert
Natural ventilation		6	7	7	7
	Mechanical ventilation	4	5	6	6
Night ventilation		6	7	7	7
	Artificial cooling	3	5	5	6
Evaporative cooling		3	2	2	7
	Free cooling	5	6	6	7
Heavy-weight construction		6	2	2	6
Light-weight construction		3	5	5	4
	Artificial heating	4	0	0	1
Solar heating		6	0	0	0
	Free heating	5	0	0	0
Incidental heat		4	0	0	0
Insulation/permeability		5	0	0	4
Solar control/shading		6	6	6	7
	Daytime artificial lighting	3	3	3	2
Day lighting features		6	5	5	4

* 0 = not important, 4 = important, and 7 = very important (importance is rated from 0 to 7)

One can define four levels of thermal mass as follows:

• Light building: no thermal mass, e.g., a mobile home.

• Medium-light building: light walls, but heavy floor, e.g., cement tiles on concrete floor, and concrete ceiling.

• Semi-heavy building: heavy floor, ceiling and external walls (20 cm concrete blocks) but light internal partitions (Gypsums boards).

• Heavy building: heavy floor, ceiling, external and internal walls (10 cm concrete blocks, with plaster on both sides).

• The exact reduction in the maximum indoor temperature depends on the amount of thermal mass, the rate of night ventilation, and the temperature swing between day and night.

3.2 Energy Efficiency and Architectural Expression

The focus of the world's attention on environmental issues in recent years has stimulated response in many countries, which have led to a closer examination of energy conservation strategies for conventional fossil fuels. Buildings are important consumers of energy and thus important contributors to emissions of greenhouse gases into the global atmosphere. The development and adoption of suitable renewable energy technology in buildings has an important role to play. A review of options indicates benefits and some problems [20-29]. There are two key elements to the fulfilling of renewable energy technology potential within the field of building design; first the installation of appropriate skills and attitudes in building design professionals and second the provision of the opportunity for such people to demonstrate their skills. This second element may only be created when the population at large and clients commissioning building design in particular, become more aware of what can be achieved and what resources are required.

Terms like passive cooling or passive solar use mean that the cooling of a building or the exploitation of the energy of the sun is achieved not by machines but by the building's particular morphological organisation. Hence, the passive approach to themes of energy savings is essentially based on the morphological articulations of the constructions. Passive solar design, in particular, can realise significant energy and cost savings. For a design to be successful, it is crucial for the designer to have a good understanding of the use of the building.

Few of the buildings had performed as expected by their designers. To be more precise, their performance had been compromised by a variety of influences related to their design, construction and operation. However, there is no doubt that the passive energy approach is certainly the one that, being supported by the material shape of the buildings has a direct influence on architectural language and most greatly influences architectural expressiveness [30]. Furthermore, form is a main tool in architectural expression. To give form to the material things that one produces is an ineluctable necessity. In architecture, form, in fact, summarises and gives concreteness to its every value in terms of economy, aesthetics, functionality and, consequently, energy efficiency [31]. The target is to enrich the expressive message with forms producing an advantage energy-wise. Hence, form, in its geometric and material sense, conditions the energy efficiency of a building in its interaction with the environment. It is, then, very hard to extract and separate the parameters and the elements relative to this efficiency from the expressive unit to which they belong. By analysing energy issues and strategies by means of the designs, of which they are an integral part, one will, more easily, focus the attention on the relationship between these themes, their specific context and their architectural expressiveness. Many concrete examples and a whole literature have recently grown up around these subjects and the wisdom of forms and expedients that belong to millennia-old traditions has been rediscovered. Such a revisiting, however, is only, or most especially, conceptual, since it must be filtered through today's technology and needs; both being almost irreconcilable with those of the past. Two among the historical concepts are of special importance. One is rooted in the effort to establish rational and friendly strategic relations with the physical environment, while the other recognises the interactions between the psyche and physical perceptions in the creation of the feeling of comfort. The former, which may be defined as an alliance with the environment deals with the physical parameters involving a mixture of natural and artificial ingredients such as soil and vegetation, urban fabrics and pollution [32]. The most dominant outside parameter is, of course, the sun's irradiation, our planet's primary energy source. All these elements can be measured in physical terms and are therefore the subject of science. Within the second concept, however, one considers the emotional and intellectual energies, which are the prime inexhaustible source of renewable power [33]. In this case, cultural parameters, which are not exactly measurable, are involved. However, they represent the very essence of the architectural quality. Objective scientific measurement parameters tell us very little about the emotional way of perceiving, which influences the messages of human are physical sensorial organs. The perceptual reality arises from a multitude of sensorial components; visual, thermal, acoustic, olfactory and kinaesthetics. It can, also, arise from the organisational quality of the space in which different parameters come together, like the sense of order or of serenity. Likewise, practical evaluations, such as usefulness, can be involved too. The evaluation is a wholly subjective matter, but can be shared by a set of experiencing persons [33]. Therefore, these cultural parameters could be different in different contexts in spite of the inexorable levelling on a planet- wide scale. However, the parameters change in the anthropological sense, not only with the cultural environment, but also in relation to function. The scientifically measurable parameters can, thus, have their meanings very profoundly altered by the non-measurable, but describable, cultural parameters.

However, the low energy target also means to eliminate any excess in the quantities of material and in the manufacturing process necessary for the construction of our built environment. This claims for a more sober, elegant and essential expression, which is not jeopardising at all, but instead enhancing, the richness and preciousness of architecture, while contributing to a better environment from an aesthetic viewpoint [34]. Arguably, the most successful designs were in fact the simplest. Paying attention to orientation, plan and form can have far greater impact on energy performance than opting for elaborate solutions [35]. However, a design strategy can fail when those responsible for specifying materials for example, do not implement the passive solar strategy correctly. Similarly, cost-cutting exercises can seriously upset the effectiveness of a design strategy. Therefore, it is imperative that a designer fully informs key personnel, such as the quantity surveyor and client, about their design and be prepared to defend it. Therefore, the designer should have an adequate understanding of how the occupants or processes, such as ventilation, would function within the building. Thinking through such processes in isolation without reference to others can lead to conflicting strategies, which can have a detrimental impact upon performance. Likewise, if the design intent of the building is not communicated to its occupants, there is a risk that they will use it inappropriately, thus, compromising its performance. Hence, the designer should communicate in simple terms the actions expected of the occupant to control the building. For example, occupants should be well informed about how to guard against summer overheating. If the designer opted for a simple, seasonally adjusted control; say, insulated sliding doors were to be used between the mass wall and the internal space. The lesson here is that designers must be prepared to defend their design such that others appreciate the importance and interrelationship of each component. A strategy will only work if each individual component is considered as part of the bigger picture. Failure to implement a component or incorrect installation, for example, can lead to failure of the strategy and consequently, in some instances, the building may not liked by its occupants due to its poor performance.

3.3 Sustainable Practices

Within the last decade sustainable development and building practices have acquired great importance due to the negative impact of various development projects on the environment. In line with a sustainable development approach, it is critical for practitioners to create a healthy, sustainable built environment [36, 37]. In Europe, 50 % of material resources taken from nature are building-related, over 50 % of national waste production comes from the building sector and 40 % of energy consumption is building-related [38]. Therefore, more attention should be directed towards establishing sustainable guidelines for practitioners. Furthermore, the rapid growth in population has led to active construction that, in some instances, neglected the impact on the environment and human activities. At the same time, the impact on the traditional heritage, an often-neglected issue of sustainability, has not been taken into consideration, despite representing a rich resource for sustainable building practices.

Sustainability has been defined as the extent to which progress and development should meet the need of the present without compromising the ability of the future generations to meet their needs [38]. This encompasses a variety of levels and scales ranging from economic development and agriculture, to the management of human settlements and building practices. This general definition was further developed to include sustainable building practices and management of human settlements. The following issues were addressed during the Rio Earth Summit in 1992 [39]:

• The use of local materials and indigenous building sources.

• Incentive to promote the continuation of traditional techniques, with regional resources and self-help strategies.

• Regulation of energy-efficient design principles.

• International information exchange on all aspects of construction related to the environment, among architects and contractors, particularly non-conventional resources.

• Exploration of methods to encourage and facilitate the recycling and reuse of building materials, especially those requiring intensive energy use during manufacturing, and the use of clean technologies.

The objectives of the sustainable building practices aim to:

• Develop a comprehensive definition of sustainability that includes socio-cultural, bio-climate, and technological aspects.

• Establish guidelines for future sustainable architecture.

• Predict the CO_2 emissions in buildings.

• The proper architectural measure for sustainability is efficient, energy use, waste control, population growth, carrying capacity, and resource efficiency.

• Establish methods of design that conserve energy and natural resources.

A building inevitably consumes materials and energy resources. The technology is available to use methods and materials that reduce the environmental impacts, increase operating efficiency, and increase durability of buildings. Literature on green buildings reveals a number of principles that can be synthesised in the creation of the built environment that is sustainable. According to Lobo [40], these are: land development, building design and construction, occupant considerations, life cycle assessment, volunteer incentives and marketing programmes, facilitate reuse and remodelling, and final disposition of the structure. These parameters and many more are essential for analysis, making them an important element of the design decision-making process.

Today, architects should prepare for this as well as dealing with existing buildings with many unfavourable urban environmental factors, such as many spaces have no choice of orientation, and, often, set in noisy streets with their windows opening into dusty and polluted air and surrounding buildings overshadowing them.

3.4 Buildings and CO_2 Emission

To achieve carbon dioxide, CO_2, emission targets, more fundamental changes to building designs have been suggested [41]. The actual performance of buildings must also be improved to meet the emission targets. To this end, it has been suggested that the performance assessment should be introduced to ensure that the quality of construction, installation and commissioning achieve the design intent. Air-tightness and the commissioning of plant and controls are the main two elements of assessing CO_2 emission. Air-tightness is important as uncontrolled air leakage wastes energy. Uncertainties over infiltration rates are often the reason for excessive design margins that result in oversized and inefficient plants. On the other hand, commissioning to accept procedures would significantly improve energy efficiency. The slow turnover in the building stock means that improved performance of new buildings will only cut CO_2 emissions significantly in the long term. Consequently, the performance of existing buildings must be improved. For example, improving 3% of existing buildings would be more effective in cutting emissions than, say, improving the fabric standards for new non-domestic buildings and improving the efficiency of new air conditioning and ventilation systems [42]. A reduction in emissions arising from urban activities can, however, only be achieved by a combination of energy efficiency measures and a move away from fossil fuels.

3.5 Low Energy Buildings

There is no single, simple formula for achieving low energy buildings. The basic principle is to minimise energy demand and to optimise energy supply through a greater reliance on local and renewable resources. Cities need to take a close look at how to make more efficient use of resources while fulfilling the needs of the people. An energy dimension should be included in the development process to measure the sustainability of urban and building design and growth planning models. Previous experience in public transport systems indicates that density is conductive to profitability and efficiency [43]. A compact urban form with vertical zoning through multi-level and multi-functional urban clusters may be an efficient option for high-density living. There are, however, opportunities for high-density cities to explore and develop effective energy technologies, which can take full advantage of the concentrated loads and high-rise context, such as using district energy systems and vertical landscapes. Designing and constructing low energy buildings require the design team to follow an energy design process that considers how the building envelope and systems work together [44].

As low energy design is becoming more and more complicated, there is a need to develop analytical methods and skills, such as simulation and modelling techniques, for the evaluation of energy performance of buildings and the analysis of design options and approaches [45]. Kausch [46] pointed out that low energy building design is compatible with a wide range of architectural styles. Studio Nicoletti [47] also illustrated the methods of architectural expression for low energy buildings in their projects. For high-density conditions, some of their methods are still valid but adaptation or modification may be needed to satisfy the local requirements. Climate consideration is a key element and starting point for formulating building and urban design principles that aim at minimising the use of energy for environmental control. In densely populated areas, analysis of the climatic and solar conditions is critical for the design optimisation. It should be noted that in urban areas, the group of buildings would in fact modify the climatic conditions surrounding it.

Measures to maximise the use of high-efficiency generation plants and on-site renewable energy resources are important for raising the overall level of energy efficiency. For renewable energy systems, energy storage is still the major technical constraint to their applications [48]. Loads concentration in high-density cities might provide opportunities for better utilisation of renewable energy systems. At present, lack of incentives and shortage of land and space are the key factors limiting the deployment of renewable energy systems. High-rise buildings and high population density make it difficult to find suitable locations for solar collectors and equipment. As the demand for heating energy is relatively low in many buildings because of the warm climate throughout the year, the economic advantage of directly using solar heat is weakened. To promote renewables, it is necessary to create new development patterns and shift from a centralised view of energy sector to a regional perspective [49]. One important aspect often being overlooked is the raising of awareness and the education about low energy design.

More efforts are needed to educate the people and establish the culture so that more people would accept and consider low energy buildings an important element of their living and working environment. It is important to recognise that solutions to the energy problems are not simply a matter of applying technology and enforcement through legislation [50]. It requires public awareness and participation as well. Therefore, measures to promote public awareness and education are crucial for the implementation of energy efficiency and renewable energy policies.

In summary, achieving low energy building requires comprehensive strategy that covers; not only building designs, but also considers the environment around them in an integral manner. Major elements for implementing such a strategy are as follows.

3.5.1 Efficiency use of Energy

• Climate responsiveness of buildings.

•Good urban planning and architectural design.

• Good housekeeping and design practices.

• Passive design and natural ventilation.

• Use landscape as a means of thermal control.

Table 3: Recent Assessments of Comparative Costs of Turbine and Diesel Pump

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Water Current Turbine													
Cost	6750												
Installation &training	450												
yrs spares 3					972			972			972		
Annual Maintenance		90	90	90	90	90	90	90	90	90	90	90	90
yrs maintenance 3					90			90			90		
Annual cost	7200	90	90	90	1152	90	90	1152	90	90	1152	90	90
Accumulation Cost	7200	7290	7380	7470	8622	8712	8802	9954	10044	10134	11286	11376	11466
Diesel Pump “3													
Cost	2000												
Fuel		1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080	1080
Oil		135	135	135	135	135	135	135	135	135	135	135	135
Grease		6	6	6	6	6	6	6	6	6	6	6	6
Spares & Maintenance			200	400	400	400	400		200	400	400	400	400
Annua1 cost	2000	1221	1421	1621	1621	1621	1621	1221	1421	1621	1621	1621	1621
Accumulation Cost	2000	3221	4642	6263	7884	9505	11126	12347	13768	15389	17010	18631	20252
WCT – Diesel Pump	5200	4069	2738	1207	738	-793	-2324	-2393	-3724	-5255	-5724	-7255	-8786

Note: Figures shown in D.S * 100

• Energy efficiency lighting.

• Energy efficiency air conditioning.

• Energy efficiency household and office appliances.

• Heat pumps and energy recovery equipment.
• Combined cooling systems.

• Fuel cells development.

3.5.2 Utilise Renewable Energy

• Photovoltaics.
• Wind energy.
• Small hydros.
•Waste-to-energy.
• Landfill gas.
• Biomass energy.

• Biofuels. **(Table 3)**

3.5.3 Reduce Transport Energy

• Reduce the need to travel.

• Reduce the level of car reliance.

• Promote walking and cycling.

• Use efficient public mass transport.

• Alternative sources of energy and fuels.

3.5.4 Increase Awareness

• Promote awareness and education.

• Encourage good practices and environmentally sound technologies.

• Overcome institutional and economic barriers.

• Stimulate energy efficiency and renewable energy markets.

4. Discussion

A number of years of data on the solar radiation on horizontal surface, sunshine duration, and wind speed in Sudan have been compiled, evaluated and presented in this study. Measurements of global solar radiation on horizontal surface at 16 stations for couples of years are compared with predictions made by several independent methods. In the first method, Angstrom formula was used to correlate relative global solar irradiance to the corresponding relative duration of bright sunshine. Regression coefficients are obtained and used for prediction global solar irradiance. The predicted values were consistent with measured values (± 8.01 % variation). In the second method, by Barbaro et al., sunshine duration, and minimum air mass were used to derive an empirical correlation for the global radiation. The predicted values compared well with measured values (± 12 % variation). The diffuse solar irradiance is estimated using Page's, Lui and Jordan's correlations. The results of the two formulas have a close agreement. Radiation map of Sudan was prepared from the estimated radiation values. The annual daily mean global radiation ranges from 3.05 - 7.62 $kWhm^{-2}$ per day. Routine wind data from 70 stations were analysed. Monthly average wind speeds, and average powers were determined for each station. The derived annual average speeds range from 1.53 to 5.07 ms^{-1}. Maximum extractable average wind powers were found to vary between 1.35 and 49.5 Wm^{-2}. Wind map of Sudan was also prepared.

Figure 1: Annual Average Wind Speeds of Sudan (ms^{-1})

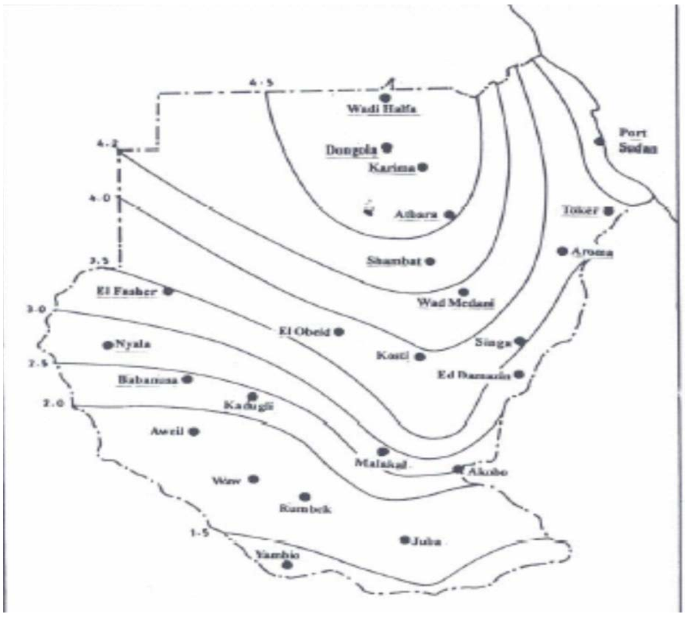


Figure 2 Yearly wind probability density (k = 1.99, c = 7.81ms^{-1}. Figure 3 Schematic of the construction of the wind pump.

Figure 2: Yearly Wind Probability Density (k = 1.99, c = 7.81ms^{-1})

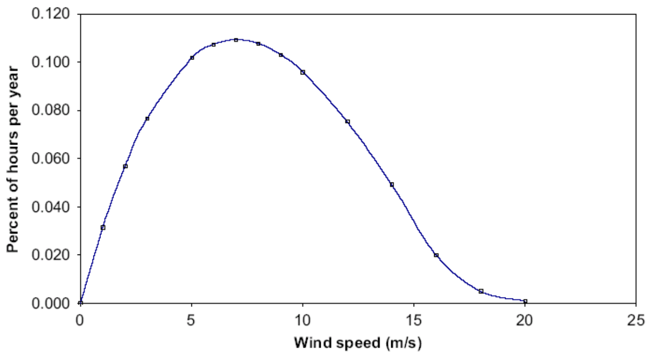
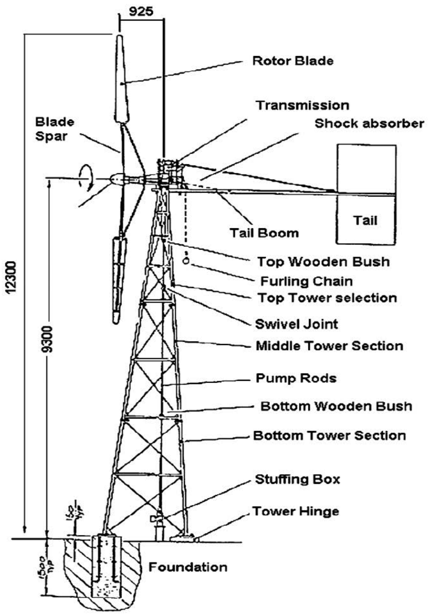


Figure 3: Schematic of the Construction of the Wind Pump



4.1 Factors Determine Consumption

Forty years ago, wind pumps were very common in central Sudan. Unfortunately, they disappeared gradually due to scarce spare parts, lack of maintenance skills as well as stiff competition from relatively cheap diesel pumps. The government reintroduced wind pumps to counter the high prices of imported diesel fuel and the difficulties in transporting it to remote areas. The following factors determine energy consumption in Sudan.

4.1.1 Urban and Rural

Substitution options for household energy in Sudan urban dwellings are electricity, LPG, kerosene/gasoline and fuelwood. Rural towns and villages are the viable consumers of wood and charcoal. Due to unavailability or un-affordability of fuelwood in these areas household consumption was shifted towards agriculture residues.

4.1.2 Occupation

Occupation pattern are different in urban/rural areas. Housewives consider themselves unemployed, through they are occupied by household management and children raising (especially in rural area) are active in farms assisting their husband.

4.1.3 Income

Highest consumption of LPG and electricity is found in higher income households. For wood and charcoal the situation is the reverse, highest consumption by low-income group and lowest by high-income groups.

4.1.4 Education

It is quite evident that the share of illiteracy developed from 2.4 % in high income households up to 58.9 % in rural low income in systematic matter which shows a direct correlation between level of income, mode of living and education (result of household survey 1994). In general illiteracy rates are higher among rural population compared to urban, with levels around 40–45 % except for Khartoum rural with 21 % illiterate.

4.1.5 Family Size

The increase in energy supplies especially biomass was mainly observed due to population growth which directly related to family size.

Figure 4 Performance of the CWD 5000. Figure 5 Locally-manufactured wind pump installed at kilo 8 site.

Figure 4: Performance of the CWD 5000

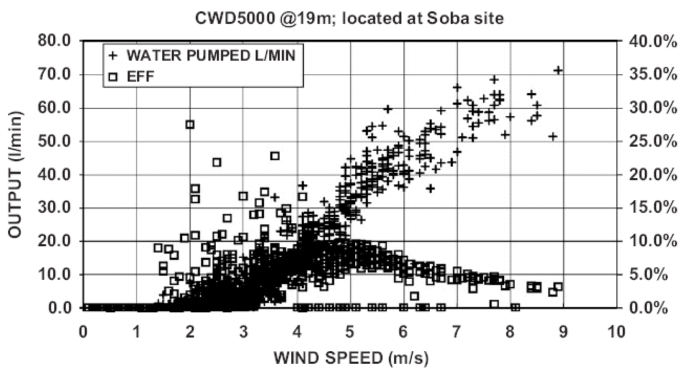


Figure 5: Locally-Manufactured Wind Pump Installed at Kilo 8 Site

4.2 Synthesis of the Renewable Energy

Although the overall impact of renewables has been necessarily low, the experience has clearly demonstrated their potential as sustainable energy alternatives. There has been substantial learning in disseminating and managing various technologies on account of:

• Scale: with increasing numbers, teething problems have been overcome and better knowledge has been gained in different aspects related to planning, implementation, operation and maintenance.

• Indigenisation: through joint ventures with international industry, the technology transfer process has been facilitated, helping in developing local production capacities.

• Infrastructure: a strong infrastructure has been created over the years to provide the technical, operational and managerial support to intervention programmes. This includes research institutions, training agencies, NGOs, financial intermediaries, etc.

Diverse strategies: though the whole renewable energy programme started with the same technology push approach, diversification occurred over a period of time in terms of strategies and to promote different technologies according to market conditions. Figure 6 Wind pump output and efficiency. Figure 7 Renewable systems over the world.

Figure 6: Wind Pumps Output and Efficiency

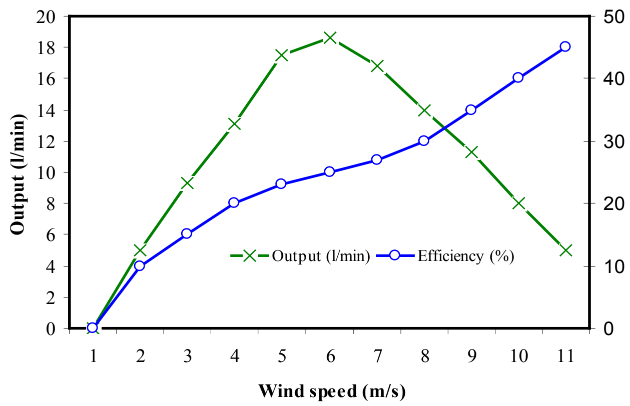
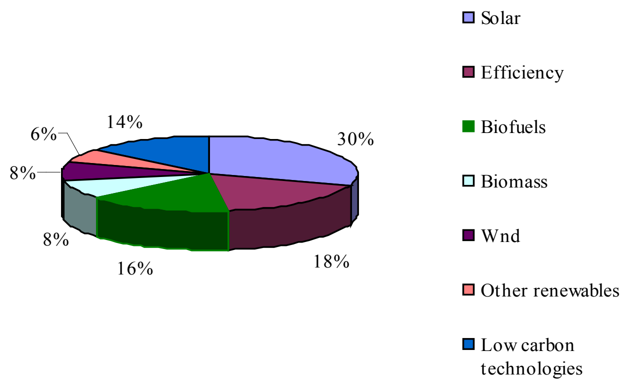


Figure 7: Renewable Systems over the World



4.2.1. Wind Power Calculation

The theoretical maximum power that can be extracted from the wind is:

$$P = \Pi * C_p * \rho_a * A * V^3 \quad (1)$$

Where:

P is the power available from wind Wm^{-2}; C_p = 16/27 = 0.593; ρ_a is the average density of air in Sudan, at the height of 10 m, taken as 1.15 kgm^{-3}; A is the area swept by rotor, projected in a plane perpendicular to the direction of wind m^2 and V is the average wind speed ms^{-1}.

Annual mean wind speeds were derived from the original monthly mean wind speeds. Annual mean wind powers were derived from monthly mean wind speeds, which were calculated according to the following procedure: given a monthly mean wind speed V, the maximum extractable monthly mean wind power per unit cross-sectional area, P is given by [8]:

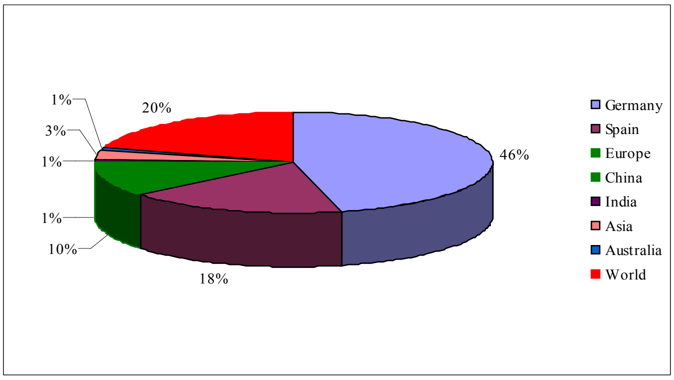
$$P = 0.3409 * V^3 \quad (2)$$

Where:

V is in ms^{-1} and P is in Wm^{-2}.

Figure 8 Wind distributions over the world.

Figure 8: Wind Distributions over the World



A note should be added on a distinction between wind pumps for different purposes:

(1) Low lift (<6 m), high volume applications (2 pumps are available).

(2) Medium lift application (<50 m) (10 pumps).

(3) Deep-well applications (>50 m) (more than 13 pumps).

In the beginning, priority has to be given to further industrial improvement of the technology around Khartoum. Once the technology is sufficiently reliable, the focus has to shift to applications in more remote areas for irrigation and for water supply purposes. The overall specifications of modified CWD 5000 wind pump are as follows (modified by ERI):

Wind machine:

Rotor diameter = ϕ 5 m

Number of blades = 8

Tower height = 9 m

Transmission = Crankshaft & connecting rod

Safety mechanism = Furling system

Pump:

Diameter = ϕ 76 mm

Stroke = 20 cm

Static head = 20 m

Cut-in wind seed = 4 ms^{-1}

Rated wind speed = 9 ms^{-1}

Cut-out wind speed =12 ms^{-1}

The actual value that can be achieved practically is less than the above because of mechanical losses and aerodynamic problems, which are not considered in collection the 0.593 value.

The most obvious region to start with seems to be the northern region because of a combination of:

(1) Good wind regime.

(2) Shallow ground water level 5-10 m depth.

(3) Need for additional rural water supply.

(4) Existing institutional infrastructure: National Company for Manufacturing Water Equipment Limited (NCMWE), Sahara Engineering Company, Sudanese Agricultural Bank (SAB).

4.2.2 Cost Comparison of Diesel and Wind Pumps

Two types of water lifting from ground water (40 m deep) are distinguished:

(1) A borehole of 35-40 m deep with 18 HP = 13.3 kW diesel engine-turbine pump.

(2) A borehole of 25-30 m deep with CWD 5000 wind pump.

A tentative cost comparison was made of a diesel engine pump and the CWD 5000 wind pump as shown in Table 4, using the most common formula:

$$CT = (A + F \times P + M)/v \quad (3)$$

Where CT is the total cost-based on initial capital cost, life, and discount rate; F is the total fuel consumption; P is the fuel cost per litre; M is the maintenance cost; and v is the volume of water pumped.

The annual cost is the function of the capital cost which is calculated by the interest rate and the life of the system [52].

$$A = [C \times I \times (I+1)]^{T}/[I+1]^{T-1} \quad (4)$$

Where A is the annual cost; C is the capital cost; I is the interest rate or discount rate; and T is the lifetime.

Figure 9 Conventional energies. Figure 10 Wind plants in Europe. Figure 11 Energy conservation measures.

The comparison indicates that the necessary fuel and maintenance needed to run the diesel pump unit long-term is the main factors, which govern the overall cost, and not the capital cost of the diesel pump itself. Therefore, in the case of Sudan where the fuel is expensive, the supply is uncertain, the infrastructure is poor, and areas are remote, the use of wind machines is the ideal.

The following is concluded:

(1) The initial investment cost of wind pumps is high; this may be a scale problem.

(2) Maintenance costs in some areas are too high for the user.

(3) The pumping costs are more or less the same.

(4) Parallel and integrated projects could reduce costs.

(5) Local production versus import: one of the perceptions is the installation of local production.

(6) Utilities and water authorities should set up in and take over responsibilities regarding technology and investment.

(7) There are substantial power production fluctuations due to variation in wind speed, and using storage devices can smooth these out.

Table 4: Cost Comparison of Diesel and Wind Pumps in Sudanese Dinar (S.D)

Specification	Diesel pump	Wind pump
Cost of borehole deep well	182400	114000
Cost of the system (purchased or fabricated in Sudan)	93600	440000
Cost of storage tank	-	420000
Cost of annual fuel consumption	343700	-
Cost of maintenance and repair	120000	110000
Total annual cost	1582100	1084000
Specific water pumping cost	79.1 per m^3	54.2 per m^3

1 US $ = S.D 250 (Sudanese Dinar), in July 2000.

Annual output 15000-20000 m^3 of water

Annual fuel consumption: Average 491 gallons and price S.D 350-700 per gallons.

Interest rate 15 %

Figure 12 shows battery lifetime versus relative annual cost (%). Figure 13 PV installed capacity (MW). Figure 14 Landfill, recycled, composted and incineration in European countries. Figure 15 PV generations in some leading countries.

The increased exploitation of renewable energy sources is central to any move towards sustainable development. However, casting renewable energy thus carries with it an inherent commitment to other basic tenets of sustainability, openness, democraticisations, etc. Due to increasing fossil fuel prices, the research in renewable energy technologies (RETs) utilisation has picked up a considerable momentum in the world. The present day energy arises has therefore resulted in the search for alternative energy resources in order to cope with the drastically changing energy picture of the world. The environmental sustainability of the current global energy systems is under serious question. A major transition away from fossil fuels to one based on energy efficiency and renewable energy is required. Alternatively energy sources can potentially help fulfil the acute energy demand and sustain economic growth in many regions of the world. The mitigation strategy of the country should be based primarily ongoing governmental programmes, which have originally been launched for other purposes, but may contribute to a relevant reduction of greenhouse gas emissions (energy-saving and afforestation programmes). Throughout the study several issues relating to renewable energies, environment and sustainable development are examined from both current and future perspectives. The exploitation of the energetic potential (solar and wind) for the production of electricity prove to be an adequate solution in isolated regions where the extension of the grid network would be a financial constraint [51, 52].

Figure 9: Conventional Energies

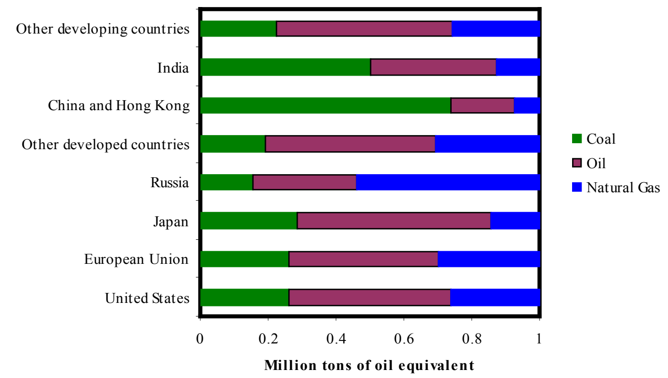


Figure 10: Wind Plants in Europe

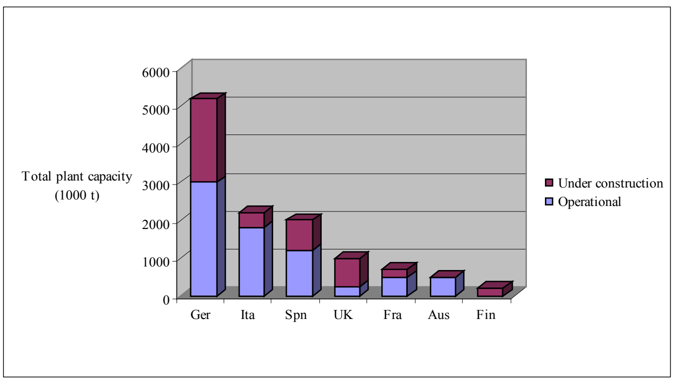


Figure 11: Energy Conservation Measures

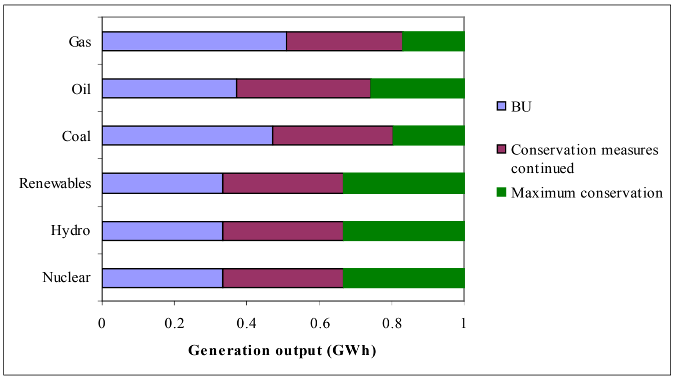
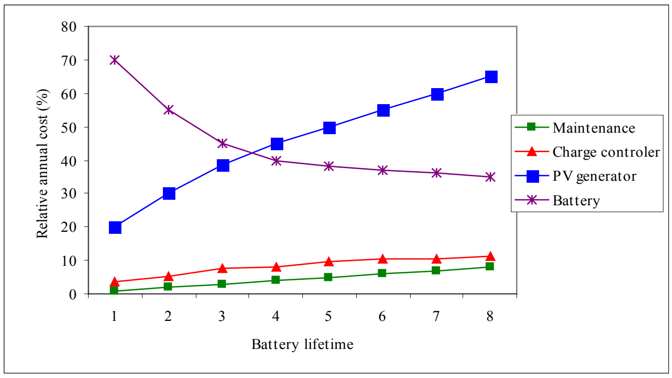


Figure 12: Battery Lifetime Versus Relative Annual Cost (%)



The provision of good indoor environmental quality while achieving energy and cost efficient operation of the heating, ventilating and air-conditioning (HVAC) plants in buildings represents a multi variant problem. The comfort of building occupants is dependent on many environmental parameters including air speed, temperature, relative humidity and quality in addition to lighting and noise. The overall objective is to provide a high level of building performance (BP), which can be defined as indoor environmental quality (IEQ), energy efficiency (EE) and cost efficiency (CE).

• Indoor environmental quality is the perceived condition of comfort that building occupants experience due to the physical and psychological conditions to which they are exposed by their surroundings. The main physical parameters affecting IEQ are air speed, temperature, relative humidity and quality.

• Energy efficiency is related to the provision of the desired environmental conditions while consuming the minimal quantity of energy.

• Cost efficiency is the financial expenditure on energy relative to the level of environmental comfort and productivity that the building occupants attained. The overall cost efficiency can be improved by improving the indoor environmental quality and the energy efficiency of a building.

Figure 13: PV Installed Capacity (MW)

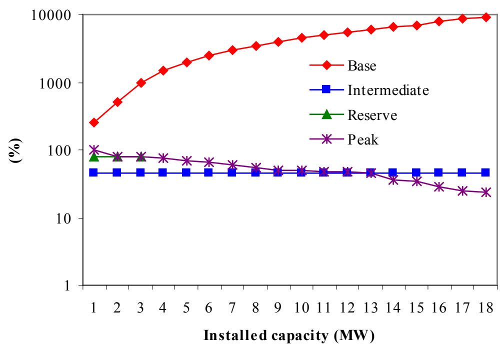


Figure 14: Landfill, Recycled, Composted and Incineration in European Countries

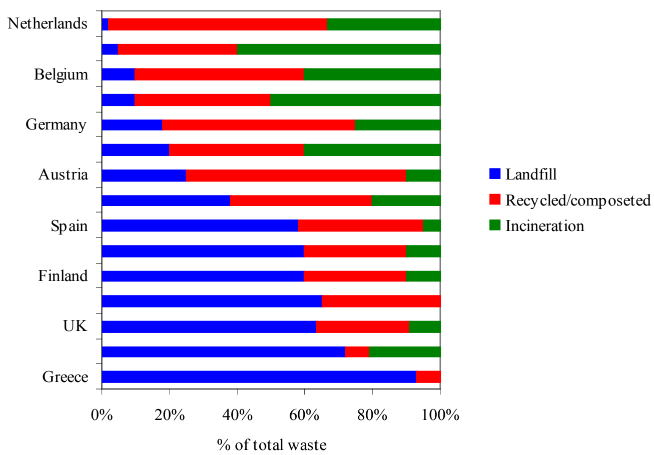


Figure 15: PV Generations in some Leading Countries

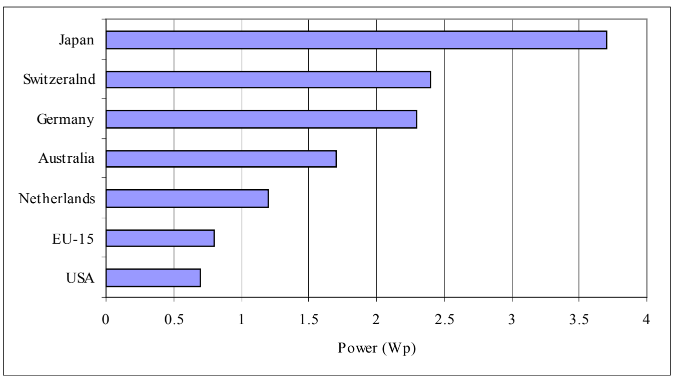
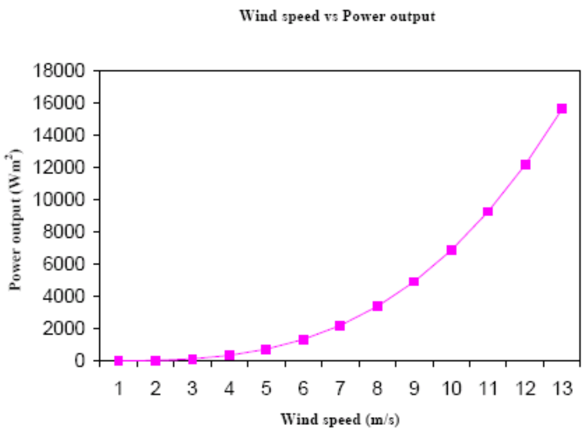


Figure 16



An expression for the volume of airflow induced by wind is:

$Q_{wind} = K A V$ (1)

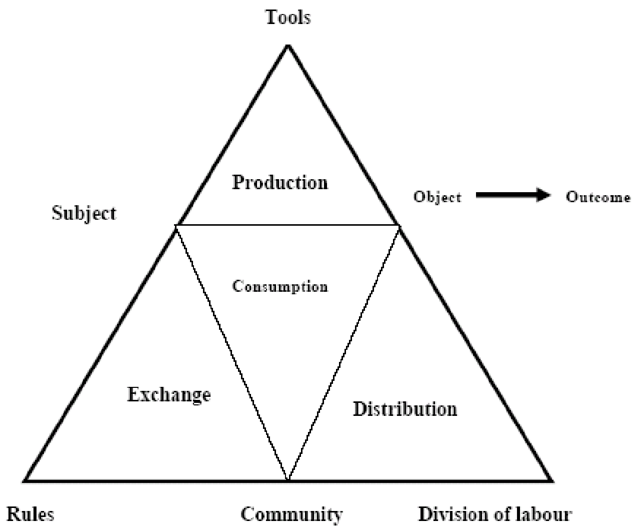
Q_{wind} is the volume of airflow (m^3/h)

A is the area of smaller opening (m^2)

V is the outdoor wind speed (m/h)

K is the coefficient of effectiveness

Figure 17



5. Results

Consideration has been given to the consistent and effective presentation of data. Original data were extracted from published reports by Sudan Metrological Department (SMD) and converted into more useful working units i.e., wind speed in miles per hour to ms^{-1}. 70 stations recorded the relative data available on wind speed and ambient temperature. Wind energy data consists of mean monthly wind speeds and wind directions measured at a height of 10 m above ground from stations throughout Sudan. Relatively accurate and properly maintained anemometers collected data. Vanes and Dines pressure-tube anemographs were used to record hourly mean wind speeds at 23 stations, other stations used beam fort estimates. For most of the stations, the recording period was greater than 10 year and average recording intervals of an hour were satisfactory. Monthly wind speed frequency distribution was also tabulated. The major parameter affecting the accuracy of the data was the exposure of the recording equipment to climate conditions, accordingly ca. 6% of the stations throughout the country were ignored in the analysis on grounds of inaccuracy. These data were utilized to determine annual wind speed frequency distribution, a major parameter in computing wind power density at a given site.

Anemometers were mounted on poles at a fixed height above ground, usually 5, 10 or 15 m. under normal conditions, wind speed were greater at higher distance above ground. This is largely because the effects of surface features and turbulence diminish as the height increases. The variability depends on distance from the ground and roughness of the terrain. It is much more difficult to predict average monthly wind speeds if the reference height at which the data were recorded is less than 6 m. Data collected at heights of less than 6 m should not be used to select a windmill or predict performance. In relatively flat areas with no trees or buildings in the immediate vicinity, site selection is not critical. However, in mountain areas or places where obstacles may block the flow of wind, differences in surface roughness and obstacles between anemometers and pump site must be taken into account when estimating wind speeds for the site. In Sudan, unequal measuring heights at different stations, in towns like Khartoum, Wad Medani, Atbara and El Obeid were measured at 15 m, in semi-towns at 10 m, and in the remaining at 5 m. The accuracy of the instruments was estimated to 5%.

In the last 15 years, the Energy Research Institute (ERI) has installed 15 'CWD 5000' wind pumps from the Netherlands around the Khartoum area and to the north and east. At the present time, the ERI, in cooperation with the Sudanese Agricultural Bank (SAB), is planning a further 60 wind pumps for water pumping in agricultural schemes, as financial support becomes available.

A distinction should be made between two applications:

• Water pumping for domestic water supply and cattle, for irrigation, drainage, prawn breeding and salt pans.

• Battery charging for lighting, T.V., radio, telecommunications, etc. (3 systems are available).

The wind pumps are categorized as:

(1) Low lift (<6 m), high volume applications (2 pumps are available).

(2) Medium lift application (<50 m) (10 pumps).

(3) Deep-well applications (>50 m) (more than 13 pumps).

Five of the wind pumps of Table (5) are locally manufactured by:

(1) National Company for Manufacturing Water Equipment Limited (3 pumps).

(2) Sahara engineering Company (1 pump).

(3) University of Wadi El Neil- Atbara (1 pump).

The basic purpose of the CWD program of the mid 1980s was for wind energy to play a significant role in meeting the rural energy needs in Sudan. This depended on a new generation of low-cost wind pump designs, which should be simple enough for local manufacture to evolve. Therefore the CWD of the Netherlands carried out consideration R & D for the Sudan wind energy project. These activities resulted in the development of acceptable wind pump designs that are suitable for application in Sudan, though the range of application may still be limited to low/medium head situations.

(1) Mean wind speeds of 4 ms^{-1} are available over 50% of Sudan, which suited for water lifting and intermittent power requirements, while there is one region in the eastern

part of Sudan that has a wind speed of 6 ms^{-1}, which is suitable for power production.

(2) The base case financial and economic analyses show that using wind pumps for remote rural water supply is cost-effective in cases where the (demand*head) product is less than 750 m^4 for wind resources of over 4 m/s.

(3) The initial investment cost of wind pumps is high, this entirely a scale problem and local mass-production facility would substantially reduce this capital cost.

(4) The substantial wind power fluctuations necessitate the use of large storage tanks. The setting up of manufacturing facilities for module easily assembled water tank is as important as the wind pump itself.

(5) According to the investigation on demand and purchasing power of the rural people, more than 60 wind pumps will be installed before year 2007. Thus the prospects for wind pumps are increasing.

6. Conclusion

Many cities around the world are facing the problem of increasing urban density and energy demand. As cities represent a significant source of growth in global energy demand, their energy use, associated environmental impacts, and demand for transport services create great pressure to global energy resources. Low energy design of urban environment and buildings in densely populated areas requires consideration of a wide range of factors, including urban setting, transport planning, energy system design, and architectural and engineering details. It is found that densification of towns could have both positive and negative effects on the total energy demand. With suitable urban and building design details, population should and could be accommodated with minimum worsening of the environmental quality.

Wind Energy

Application of wind energy available in Sudan is a major issue in the future energy strategic planning for the alternative to fossil conventional energy to provide part of the local energy demand. This communication presents potential of wind regimes available in many sites in Sudan; northern states (Dongola); eastern states (Port Sudan); and central states (Wad Medani). The meteorological parameters must be reported, and can be considered as nucleus information for executing research and development of wind energy projects; as the same time, they could determine sites that are likely to have a better prospect, and will serve as a good source of information for statistical analyses and correlation among various stations. Also, it highlights future plans concerning optimum technical, economical, and environmental utilisation of all wind energy available in Sudan. This theme presents a review of wind energy activities, including research work, studies, and pilot projects in wind energy applications, which are feasible technically and economically in Sudan. It highlights the promotion, development and demonstration of wind energy resources amongst national, regional and international organisations which involved; seek clean, safe, and abundant energy sources.

• Sudan is rich in wind, about 50 % of Sudan area is suitable for generating electricity (annual average wind speed more than 5 ms^{-1}), and 75 % of Sudan area is suitable for pumping water (annual average wind speed range between 3-5 ms^{-1}).

• In areas where there is wind energy potential, and not connected to the electric grid, the challenge is the simplicity in the design, and higher efficiency.

• The research and development in the field of wind pumps should be directed towards utilising the local skills, and the local available materials.

• Local production of wind pump should be encouraged on both public and private organisations.

Solar Energy

• Provide incentives to encourage the household sector to use solar energy.

• Invest in research and development.

• Assist in launching public awareness programmes with respect to solar energy.

• Availing training opportunities to personnel at different levels.

• Provide loans and / or grants to achieve the above objectives.

Biogas Energy

• Biogas technology cannot only provide fuel, but also important for comprehensive utilisation of biomass forestry, animal husbandry, fishery, evaluating the agricultural economy, protecting the environment, realising agricultural recycling, as well as improving the sanitary conditions, in rural areas.

• The biomass energy, one of the important options, which might gradually replace the oil in facing the increased demand for oil and may be an advanced period in the coming century. Sudan can depend on the biomass energy to satisfy part of local consumption.

• Development of biogas technology is vital component of alternative rural energy programme in Sudan, whose potential is yet to be exploited. A concerted effort is required by all if this has to be realised. The technology will find ready use in domestic, farming, and small – scale industrial applications.

• The diminishing agricultural land may hamper biogas energy development but appropriate technological and resource management techniques will offset the effects.

• Support biomass research and exchange experiences with countries that are advanced in this field. In the meantime, the biomass energy can help to save exhausting the oil wealth.

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