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Full Length Research Paper

The environmental and economical advantages of agricultural wastes for sustainability development in Sudan

Abdeen Mustafa Omer

Energy Research Institute (ERI), Khartoum, Sudan. E-mail: abdeenomer2@yahoo.co.uk.

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Sudan is enjoyed with abundant solar, wind, hydro and biomass resources. Like many tropical countries, Sudan has ample biomass resources that can be efficiently exploited in a manner that is both profitable and sustainable. Fuel-wood farming offers cost-effective and environmentally friendly energy solutions for Sudan, with the added benefit of providing sustainable livelihoods in rural areas. This article provides an overview of biomass energy activities and highlights future plans concerning optimum technical and economical utilisation of biomass energy available in Sudan. Results suggest that biomass energy technologies must be encouraged, promoted, implemented, and fully demonstrated in Sudan.

Key words: Sudan, biomass energy, biofuels, biogas, bioheat, utilisation, development.

INTRODUCTION

Biomass energy includes fuel wood, agricultural residues, animal wastes, charcoal and other fuels derived from biological sources. It currently accounts for about 14% of world energy consumption. Biomass is the main source of energy for many developed and developing countries. In Sudan, energy wood is available in the form of forest chips, fuelwood, wood waste, wood pellets and it is also produced to a very limited extent from willow crops in short rotation forestry. The major part of wood harvested in the forest area approximately 108 million hectares ends up as energy wood directly or indirectly after having been used for other purposes first. In 2000, the biomass share of the total energy consumption of the country was 87% (Omer, 1998). The possibilities of increasing fuelwood production through forestations programmes and substitution for commercial fuels are discussed later. Biogas utilisation in the rural regions is also reviewed, emphasaising its possible contribution.

Biomass refers to solid carbonaceous material derived from plants and animals. These include the residues of agriculture and forestry, animal waste and wastes from food processing operations. A small amount of solar is used in the process of photosynthesis by plants and this trapped energy can be used in various ways. Wood and grass can be dried and then burned to release heat. Plant material particularly rich in starches and sugars such as sugarcane and wheat can be fermented to produce ethanol. Alternately, methanol, which can be produced by the distillation of biomass, contains considerable cellulose such as wood and bagasse (residue from sugarcane). Both of these alcohols can be used to fuel vehicles and machinery, and can be mixed with petrol to make a petrol/alcohol blend. Although biomass energy use is predominantly in rural areas, it also provides an important fuel source for the urban poor and many rural, small and medium scale industries. In order to meet the growing demand for energy, it is imperative to focus on efficient production and uses of biomass energy to requirements (such as electricity and liquid fuels). This production of biomass in all its forms for fuel, food and fodder demands environmentally sustainable land use and integrated planning approaches (Galal, 1997). Biogas from biomass appears to have potential as an alternative energy in Sudan, which is potentially rich in biomass resources.

Energy is an essential factor in development since it stimulates, and supports economic growth and development. Fossil fuels, especially oil and natural gas, are finite in extent, and should be regarded as depleting assets, and efforts are oriented to search for new sources of energy. The clamour all over the world for the need to conserve energy and the environment has intensified as traditional energy resources continue to dwindle whilst the environment becomes increasingly degraded.

Alternatively, energy sources can potentially help fulfill the acute energy demand and sustain economic growth in many regions of the world. Bioenergy is beginning to gain importance in the global fight to prevent climate change. The scope for exploiting organic waste as a source of energy is not limited to direct incineration or burning refuse-derived fuels. Biogas, biofuels and woody biomass are other forms of energy sources that can be derived from organic waste materials. These biomass energy sources have significant potential in the fight against climate change. 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 practiced 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, biomass and water energy alternatives must be set in hand to supplement what remains of the fossil fuels. Fuel-wood farming offers cost-effective and environmentally friendly energy solutions for Sudan, with the added benefit of providing sustainable livelihoods in rural areas.

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, power plant. 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. In compiling energy consumption data one can categorise usage according to a number of different schemes:

- Traditional sector- industrial, transportation, etc.
- End-use- space heating, process steam, etc.
- Final demand- total energy consumption related to automobiles, to food, etc.
- Energy source- oil, coal, etc.
- Energy form at point of use- electric drive, low temperature heat, etc.

MAJOR ENERGY CONSUMING SECTORS

Sudan is still considered as one of the 25 most developing African countries. Agriculture is the backbone of economic and social development in Sudan. About 80% of the population depends on agriculture, and all other sectors are largely dependent on it. Agriculture contributes to about 41% of the gross national product (GNP) and 95% of all earnings. It determined the degree of performance growth of the national economy for the last 30 years. Special attention should therefore be given to reviewing forest resources, plantation programmes and the possibilities of substitution of fuelwood for commercial fuels or for other fuels such as biogas. The main sources of fuelwood supply in the country can be broadly grouped into two main categories, that is, forest sources (forests under the control of governmental forest departments) and non-forest sources (private farmland and wild lands). Women, assisted by children, almost always perform the gathering of fuelwood in rural areas of developing countries. As fuelwood became scarce, which is the case in many parts of the world, the collection time has increased and although men do not perceive it, this had many undesirable consequences, which can be clearly seen in many rural region of Sudan. This is due to women having less time for their other important social functions, such as cooking, washing, water collection, and child rearing, which may affect the nutrition and health of the entire family. Note that wood energy for many countries is one of the few locally available sources of energy, which they can afford. Hence, its substitution by imported fossil fuels, as has often been carelessly recommended, should attentively be evaluated to avoid undesirable political, economic and social consequences.

Agriculture sector

During the last decades, agriculture contributed to the Sudan GNP by about 41%, as stated above. This share remained stable until 1984 - 1985 when Sudan was seriously hit by drought and desertification, which led to food shortages and deforestation, and, also, by socio-economic effects caused by the civil war. This dropped the agriculture share to about 37%. Recent development due to rehabilitation programmes and improvement in agricultural sector in 1994 has raised the share again to 41%. This share was reflected in providing raw materials to local industries and an increased export earning besides raising percentage of employment among population. This sector consumes 2.5% of the total energy consumption (28% from electricity, 14.8% from fossil fuels, and the rest from biomass fuels).

Industrial sector

The industrial sector is mainly suffering from power shortages, which is the prime mover to the large, medium and small industries. The industrial sector was consuming 5.7% of the total energy consumption, distributed as 55% from petroleum products, 13% from biomass and 32% from electricity.

Transport sector

The transportation sector in the Sudan (railways, ships, boats, etc.) has not been efficient for the last two decades because of serious damage occurred to its infrastructure (roads, workshops, and maintenance centres, etc.) over a long period of time. However, as it stands, it consumes 10% of the total energy consumption and utilizes 60% of the total petroleum products supplied.

Domestic use

Household is the major energy consumer in the Sudan. It consumes

Table 1. Annual volume of biomass sources available in Sudan (10^6 tonnes).

Source	Volume of biomass (10^6 tonnes)
Natural and cultivated forestry	2.9
Agricultural residues	5.2
Animal wastes	1.1
Water hyacinth and aquatic weeds	3.2
Total	12.4

Table 2. Annual biomass energy consumption pattern in Sudan (10^3 m^3).

Sector	Fire wood	Charcoal	Total	Percent (%)
Residential	6148	6071	12219	88.5
Industrial	1050	12	1062	7.7
Commercial	32	284	316	2.3
Quranic schools	209	0	209	1.5
Total	7439	6367	13806	
Percent (%)	54	46		100.0

92% of the total biomass consumption in the form of firewood and charcoal. This sector also consumes 60% of the total electricity consumption, and 5.5% of petroleum products. Fuel wood, animal wastes, agricultural crop residues, and logging wastes have been used through direct burning in Sudan for many years. These sources are often called non-commercial energy sources, but in Sudan fuelwood is a tradable commodity since it is the primary fuel of rural areas and the urban poor section. Traditional fuels predominate in rural areas; almost all biomass energy is consumed in the household sector for heating, cleaning and cooking needs of rural people. Especially in the villages (households on the high plateau) the preparation of three stone fires is very attractive to the villagers. In this method, food and plant residues are put in a large boiler with water and cooked on a traditional stove outside the house for animal feed, because cooked food and plant residues are cheaper than flour and bran. Nevertheless, this method consumes much more fuelwood than the cooking on the stoves method. On the other hand, wood is the most practical fuel for serving a large number of people because the size of the batch of food is only limited by the volume of the pot and not by the size of the stove's burner. Fuelwood is also convenient for cooking of the meal of meat.

BIOMASS RESOURCES

Agriculture is the source of a considerable sum of hard currency that is needed for the control of balance of payment in the country's budget, as well as it is the major source of raw materials for local industry. Biomass resources play a significant role in energy supply in Sudan as in all other developing countries. Biomass resources should be divided into residues and dedicated resources; the latter including firewood and charcoal from forest resources. As shown in Table 1, approximately 12.4×10^6 m^3 of biomass are consumed per year. Table 2 shows the division of this between the various sectors. To avoid resource depletion, Sudan is currently undergoing a reforestation programme of 1.05×10^6 hectares. However, biomass residues are more economically exploitable and more environmentally benign than dedicated biomass resources (Hood, 1994). There exists a variety of readily available sources in Sudan, including agricultural residues such as sugar cane bagasse, and molasses, cotton stalks, groundnut shells, tree/forest residues, aquatic weeds, and various animal wastes as shown in Table 3. The aim of any modern biomass energy systems must be:

- To maximize yields with minimum inputs.
- Utilisation and selection of adequate plant materials and processes.
- Optimum use of land, water, and fertilizer.
- Create an adequate infrastructure and strong R and D base.

Direct burning of fuel-wood and crop residues constitute the main usage of Sudan's biomass, as is the case with many developing countries. However, the direct burning of biomass in an inefficient manner causes economic loss and adversely affects human health. In order to address the problem of inefficiency, research centres around the country are investigating the viability of converting the residue to a more useful form, namely solid briquettes and fuel gas. Briquetting is the formation of a char (an energy-dense solid fuel source) from otherwise wasted agricultural and forestry residues. One of the disadvantages of wood fuel is that it is bulky and therefore requires the transportation of large volumes. Briquette formation, on the other hand, allows for a more energy-dense fuel to be delivered, thus reducing the transportation cost and making the resource more competitive. It also adds some uniformity, which makes the

Table 3. Biomass residues, current use and general availability.

Type of residue	Current use / availability
Wood industry waste	No residues available
Vegetable crop residues	Animal feed
Food processing residue	Energy needs
Sorghum, millet and wheat residues	Fodder and building materials
Groundnut shells	Fodder, brick making and direct fining oil mills
Cotton stalks	Domestic fuel considerable amounts available for short period
Sugar, bagasse and molasses	Fodder, energy need and ethanol production (surplus available)
Manure	Fertilizer, brick making and plastering (*Zibala*)

Table 4. Effective biomass resource utilisation.

Subject	Tools	Constraints
Utilisation and land clearance for agriculture expansion	Stumpage fees	Policy
	Control	Fuel-wood planning
	Extension	Lack of extension
	Conversion	Institutional
	Technology	
Utilisation of agricultural residues	Briquetting	Capital
	Carbonisation	Pricing
	Carbonisation and briquetting	Policy and legislation
	Fermentation	Social acceptability
	Gasification	

fuel more compatible with systems that are sensitive to the specific fuel input (NEA, 1982). Briquetting of agricultural residues in Sudan started in 1980, with a small briquetting plant using groundnut shells in Khartoum. The second plant was introduced in Kordofan (western Sudan) with a capacity of 2 tonnes per hour with maximum 2000 tonnes per season. Another prototype unit was installed in Nyala with capacity of 0.5 tonnes per hour (that is, 600 tonnes per season). In central Sudan, a briquetting plant of cotton stalks was installed at Wad El Shafie with a capacity of 2 tonnes per hour (that is, 2000 tonnes per season). An ongoing project in New Halfa was also constructed to produce 1200 tonnes per season of bagasse briquettes (NEA, 1993). A number of other factories were built in central Sudan for carbonisation of agricultural residues, namely cotton stalks (Omer, 1996a). The products are now commercialised and more than 2000 families have been trained to produce their cooking charcoal from the cotton stalks.

Gasification is based on the formation of a fuel gas (mostly CO and H_2) by partially oxidising raw solid fuel at high temperatures in the presence of steam. The technology, initially developed for use with charcoal as fuel input, can also make use of wood chips, groundnut shells, sugar cane bagasse, and other similar fuels to generate capacities from 3 - 100 kW for biomass systems. Three gasifier designs have been developed to make use of the diversity of fuel inputs and to meet the requirements of the product gas output (degree of cleanliness, composition, heating value, etc.) (ERI, 1987). Furthermore, Sudan is investigating the potential to make use of more and more of its waste. Household waste, vegetable market waste and waste from the cotton stalks, leather, pulp, and paper industries can be used to produce useful energy by direct incineration, gasification, digestion (biogas production), fermentation, or cogeneration.

The use of biomass through direct combustion has long been, and still is the most common mode of biomass utilisation in the Sudan, as implied in Tables 3, 4 and 5. Examples of dry (thermo-chemical) conversion processes are charcoal making from wood (slow pyrolysis), gasification of forest and agricultural residues (fast pyrolysis), and of course, direct combustion in stoves, furnaces, etc. Wet processes, on the other hand, require substantial amount of water to be mixed with the biomass.

In Sudan, most urban households burn charcoal on traditional square ‘‘Canun’’ stoves that have very low fuel-to-heat conversion efficiencies. The following prototypes were all tried and tested in Sudan:

- The metal clad Kenyan Jiko.
- The vermiculite lined traditional Kenyan Jiko.
- The all-ceramic Jiko in square metal box.
- The open draft Dugga stoves.

Table 5. Agricultural residues routes for development.

Source	Process	Product	End use
Agricultural residues	Direct	Combustion	Rural poor
			Urban household
			Industrial use
	Processing	Briquettes	Industrial use
			Limited household use
	Processing	Carbonisation (small-scale)	Rural household (self sufficiency)
			Urban fuel
	Carbonisation	Briquettes	
		Carbonised	Energy services
	Fermentation	Biogas	Household
			Industry
Agricultural and animal residues	Direct	Combustion	(Save or less efficiency as wood)
			(Similar end use devices or improved)
	Briquettes	Direct combustion	Use
		Carbonised	Briquettes use
	Carbonisation	Briquettes	Use
	Carbonisation	Biogas	
	Fermentation		

- The controlled draft Dugga stoves.
- The Umeme Jiko ‘‘Canun Al Jadeed’’.

Another area in which rural energy availability could be secured where woody fuels have become scarce, are the improvements of traditional cookers and ovens to raise the efficiency of fuel saving (NEA, 1991). Also, planting fast growing trees to provide a constant fuel supply should be seriously considered. Note that the energy development is essential and economically important since it will eventually lead to better standards of living, people’s settlement, and self sufficient in food and water supplies, better services in education and health care and good communication modes (NEA, 1985; Ali and Huff, 1984). Local traditional stoves were also tested, improved, invested, and commercially used in the Sudan (ERI, 1987). These include:

- Traditional muddy stoves.
- Bucket stoves.
- Tin stoves.

SUGAR CANE BIOMASS

Residuals from the sugar cane industry represent by far the most important source of current and potential biomass resources in Sudan. The sugar industry in Sudan goes back fifty years. Sugar cane plantations cover one fifth of the arable land in Sudan. In addition, to raw sugar, Sudan enterprises produce and utilize many valuable cane co-products as food for energy and fibre. At present, there are 5 sugar factories. Sugar cane bagasse and sugar cane trash already provide a significant amount of biomass for electricity production, but the potential is much higher with advanced cogeneration technologies. Most sugar factories in Sudan can produce about 15 - 30 kWh per ton of cane. If all factories were fitted with biomass gasifier-combined cycle systems, 400 - 800 kWh of electricity could be produced per ton of cane, enough to satisfy all Sudan’s current electricity demand. This would further be facilitated by the fact that some of the sugar plants are near electric grids (Kenana, El Genaid, Sennar and Asalaia) and others have their own grids. Additionally, alcohol could be produced as a by-product of the sugar industry. In Sudan, there have been no alcohol distilleries since 1983. The three factories before then were closed due to the implementation of the Sharia Laws. However, alcohol is used for a variety of applications, mainly for medical purposes and rum production. The current circumstances suggest that Sudan should consider expanding production for use as transportation fuel, but this option has not yet been pursued.

BIOGAS

At present, Sudan uses a significant amount of kerosene, diesel, firewood, and charcoal for cooking in many rural areas. Biogas technology was introduced to Sudan in the mid seventies when GTZ designed a unit as a side-work of a project for water hyacinth control in central Sudan. Anaerobic digesters producing biogas (methane) offer a sustainable alternative fuel for cooking that is appropriate

Table 6. Energy carrier and energy services in rural Sudan.

Energy carrier	Energy end-use	Typical annual household consumption
Fuel-wood	Cooking	10 tonnes
	Water heating	
	Building materials	
	Animal fodder preparation	
Kerosene	Lighting	100 L
	Ignition fires	
Dry cell batteries	Lighting	50 pairs
	Small appliances	
Animal power	Transport	
	Land preparation for farming	
	Food preparation (threshing)	
Human power	Transport	
	Land preparation for farming	
	Food preparation (threshing)	

and economic in rural areas. There are currently over 200 installed biogas units in the Sudan, covering a wide range of scales appropriate to family, community, or industrial uses. The agricultural residues and animal wastes are the main sources of feedstock for larger scale biogas plants.

There are in practice two main types of biogas plant that have been developed in Sudan: the fixed dome digester, which is commonly called the Chinese digester (120 units; each with volumes 7 - 15 m^3). The other type is with floating gasholder known as Indian digester (80 units; each with volumes 5 - 10 m^3). The solid waste from biogas plants adds economic value by providing valuable fertiliser as by-products (Ali and Shommo, 1993; GTZ, 1985). Biogas technology can not only provide fuel, but also important for comprehensive utilisation of biomass forestry, animal husbandry, fishery, evolution of the agricultural economy, protecting the environment, realizing agricultural recycling, as well as improving the sanitary conditions, in rural areas. The introduction of biogas technology on wide scale has implications for macro planning such as the allocation of government investment and effects on the balance of payments. Factors that determine the rate of acceptance of biogas plants, such as credit facilities and technical backup services, are likely to have to be planned as part of general macro-policy, as do the allocation of research and development funds (Omer, 1994, 1996b).

BIOENERGY POTENTIAL

For efficient use of Bioenergy resources, it is essential to take account of the intrinsic energy potential. Despite the availability of basic statistics, many differences have been observed between the previous assessments of Bioenergy potential (D'Apote, 1998; World Bank, 2001; FAO, 1999; NFA, 1994). These were probably due to different assumptions or incomplete estimations of the availability, accessibility and use of by-products. However, the biomass sources have been used through:

- Direct combustion of forestry and wood processing residues.
- Direct combustion in the case of main dry crop residues.
- Anaerobic digestion of municipal wastes and sewage.
- Anaerobic digestion of moist residues of agricultural crops and animal wastes.

Wood is very important raw material used by a number of industries. Its excessive utilisation as a fuel results in soil erosion, degradation of the land, reduced agricultural productivity and potentially serious ecological damage. Hence, minimisation of fuelwood demand at a national level and the incremental increase in the efficiency of fuelwood use seem to be essential. Utilisation of more efficient stoves and improvement of insulation using locally available materials in buildings are also effective measures to increase efficiency. Biogas or commercial fuels may be thought of as possible substitutes for fuelwood. Table 6 suggests that liquefied petroleum gases (LPG), such as kerosene, are strong candidate to replace firewood in rural areas of Sudan. Indeed, increased, LPG utilisation over the last decade has been one of the main reasons that led to the deceleration of the diffusion of biogas technology into rural areas.

On the other hand, biomass gasification is a technology that transforms solid biomass into syngas (hydrogen and carbon monoxide mixtures produced from carbonaceous fuel). Current use of biomass (gas or solid), which stands at about 87% of the total energy supply in Sudan, is primarily used in combustion for immediate use. Biomass fuels are characterised by high and variable moisture content, low ash content, low density, and fibrous structure

structure. In comparison with other fuels, they are regarded as of low quality despite low ash content and very low Sulphure content (Haripriye, 2000; Hall and Scrase, 1998). However, small-scale gasification for combined heat and power (CHP), also called embedded generation, is feasible. Many villages and mini-grids can be served by biomass power generation in the size range from 1 kWe - 5 MWe.

Environmental advantages

Potential mitigation measures to decrease greenhouse gas (GHG) emissions from the oil industry and decelerate the threat of global climate change may include the following:

- Controlling GHGs emissions by improving the efficiency of energy use, changing equipment and operating procedures.
- Controlling GHGs emission detection techniques in oil production, transportation and refining processes in Sudan and more efficient use of energy-intensive materials and changes in consumption patterns.
- A shift to low carbon fuels, especially in designing new refineries. The development of alternative energy sources (e.g., biomass, solar, wind, hydro-electrical and cogeneration).
- The development of effective environment standards, policies, laws and regulations particularly in the field of oil industry.
- Activating, supporting environmental, and pollution control activities within the Ministry of Energy and Mining (MEM) to effectively cope with the evolving oil industry in Sudan.

This list shows that biomass and renewable energy sources in general, have an important role to play in protecting the environment, a potential that need to be taken seriously.

Barriers to implementation

The afforestation programme appears an attractive option for the country to pursue in order to reduce the level of atmospheric carbon by enhancing carbon sequestration in the nation's forests, which would consequently mitigate climate change. However, it is acknowledged that certain barriers need to be overcome if the objectives were to be fully achieved. These include the following:

- Low level of public awareness of the economic /environmental benefits of forestry. The generally low levels of individual income and pressures from population growth.
- The land tenural system, which makes it difficult (if at all possible) for individuals to own or establish forest plantations.
- Poor pricing of forest products especially in the local market.
- Inadequate financial support on the part of governments.
- Weak institutional capabilities of the various Forestry Departments as regards technical manpower to effectively manage tree plantations.

Energy use and the environment

Energy use is one of several essential components for developing countries:

- The overall situation and the implications of increased energy use in the future.
- The problem of the provision of power in rural areas, including the consideration of energy resources and energy conversion.

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. 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, 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.

Energy ratio is defined as the ratio of:

Energy content of the food product/Energy input to produce the food (1)

The atmospheric emissions of fossil fuelled installations are mosty aldehydes, carbon monoxide, nitrogen oxides, sulpher oxides and particles (that is, ash) as well as carbon dioxide. Table 7 listed methods of energy conversion. Table 8 shows estimates include not only the releases occuring at the power plant itself but also cover fuel extraction and treatment, as well as the storage of wastes and the aea of land required for operations.

Combined heat and power (CHP) installations are quite common in greenhouses, which grow high-energy, input

Table 7. Methods of energy conversion.

Muscle power	**Man and animals**
Internal combustion engines	
Reciprocating	Petrol- spark ignition
	Diesel- compression ignition
	Humphrey water piston
Rotating	Gas turbines
Heat engines	
Vapour (Rankine)	
Reciprocating	Steam engine
Rotating	Steam turbine
Gas Stirling (Reciprocating)	Steam engine
Gas Brayton (Rotating)	Steam turbine
Electron gas	Thermionic, thermoelectric
Electromagnetic radiation	Photo devices
Hydraulic engines	Wheels, screws, buckets and turbines
Wind engines (wind machines)	Vertical axis and horizontal axis
Electrical/mechanical	Dynamo/alternator and motor

Table 8. Annual greenhouse emissions from different sources of power plants.

Primary source of energy	**Emissions**		**Waste (× 10^3 metric tons)**	**Area (km^2)**
	Atmosphere	**Water**		
Coal	380	7 - 41	60-3000	120
Oil	70 - 160	3 - 6	negligible	70 - 84
Gas	24	1	-	84
Nuclear	6	21	2600	77

crops (e.g., salad vegetables, pot plants, etc.). Scientific assumptions for a short-term energy strategy suggest that the most economically efficient way to replace the thermal plants is to modernise existing power plants to increase their energy efficiency and to improve their environmental performance. However, utilisation of wind power and the conversion of gas-fired CHP plants to biomass would significantly reduce the dependence on imported fossil fuels. Although a lack of generating capacity is forecast in the long-term, utilisation of the existing renewable energy potential and the huge possibilities for increasing energy efficiency are sufficient to meet future energy demands in the short-term (Robinson, 2007).

Most of the heat is produced by large CHP plants (gas-fired combined cycle plants using natural gas, biomass, waste or biogas). DH is energy efficient because of the way the heat is produced and the required temperature level is an important factor. Buildings can be heated to temperature of 21°C and domestic hot water (DHW) can be supplied with a temperature of 55°C using energy sources that are most efficient when producing low temperature levels (<95°C) for the DH water. Most of these heat sources are CO_2 neutral or emit low levels. Only a few of these sources are available to small individual systems at a reasonably cost, whereas DH schemes because of the plant's size and location can have access to most of the heat sources and at a low cost. Low temperature DH, with return temperatures of around 30 - 40°C can utilise the following heat sources:

- Efficient use of CHP by extracting heat at low calorific value (CV).
- Efficient use of biomass or gas boilers by condensing heat in economisers.
- Efficient utilisation of geothermal energy.
- Direct utilisation of excess low temperature heat from industrial processes.
- Efficient use of large-scale solar heating plants.

Heat tariffs may include a number of components such as a connection charge, a fixed charge and a variable energy charge. In addition, consumers may be incentivised to lower the return temperature. Hence, it is difficult to generalise but the heat practice for any DH company no matter what the ownership structure can be highlighted as follows:

- To develop and maintain a development plan for the connection of new consumers.
- To evaluate the options for least cost production of heat. To implement the most competitive solutions by signing agreements with other companies or by implementing own investment projects.
- To monitor all internal costs and with the help of benchmarking, improve the efficiency of the company.
- To maintain a good relationship with the consumer and deliver heat supply services at a sufficient quality.

Installing DH should be pursued to meet the objectives for improving the environment through the improvement of energy efficiency in the heating sector. At the same time, DH can serve the consumer with a reasonable quality of heat at the lowest possible cost. The variety of possible solutions combined with the collaboration between individual companies, the district heating association, the suppliers and consultants can, as it has been in Denmark, be the way forward for developing DH in the United Kingdom (Wu, and Boggess, 1999).

Sudan is an agricultural country with fertile land, plenty of water resources, livestock, forestry resources, and agricultural residues. Sudan energy showed the domination of biomass more than 80% and the household sector consumed more than 70% of the total biomass. Thus, the Sudanese energy institutions adopted a strategy focusing on the promotion of conservation measures and introduction of alternative techniques such as direct briquetting and charring oil available agricultural residues and aquatic weeds. Water hyacinth (Eichhornia Crassipes Solms) is a free-floating aquatic plant, which causes much trouble for navigation in Sudan particularly along White Nile from Kosti up to Malakal (200,000 tons of wet water hyacinth annually). The water hyacinth as a wet substrate represents a promising candidate for biogas production by an aerobic fermentation and has been practiced since mid seventies in Sudan. In Sudan, there are currently over 200 installed biogas units, covering a wide range of scales appropriate to family, community, or industrial uses. The agricultural residues and animal wastes are the main sources of feedstock for larger scale biogas plants. The production energy from agricultural biomass seems a realistic option for the future. Some solutions are technically feasible in short term. In some cases environmental, social and politic considerations justify their immediate exploitation even if economic evaluations of merely direct production costs do not justify at the moment the investments necessary.

Biomass is a renewable energy source, which can be converted into liquid fuels and/or gas fuels with different technologies available today. Ethanol production via fermentation, extraction and extractive-distillation is one such method and has been practiced for long time in most developing countries with agricultural surplus. However, the intensive research and development activities still needed. Furthermore, investigating the potential to make use of more and more of its waste, household waste, vegetable market waste, and waste from the cotton stalks, leather, and pulp; and paper industries can be used to produce useful energy either by direct incineration, gasification, digestion (biogas production), fermentation or cogeneration. Therefore, effort has to be made to reduce fossil energy use and to promote green energies, particularly in the building sector. Energy use reductions can be achieved by minimising the energy demand, by rational energy use, by recovering heat and the use of more green energies. This study was a step towards achieving that goal. The adoption of green or sustainable approaches to the way in which society is run is seen as an important strategy in finding a solution to the energy problem. The key factors to reducing and controlling CO_2, which is the major contributor to global warming, are the use of alternative approaches to energy generation and the exploration of how these alternatives are used today and may be used in the future as green energy sources. Even with modest assumptions about the availability of land, comprehensive fuel-wood farming programmes offer significant energy, economic and environmental benefits. These benefits would be dispersed in rural areas where they are greatly needed and can serve as linkages for further rural economic development. The nations as a whole would benefit from savings in foreign exchange, improved energy security, and socio-economic improvements. With a nine-fold increase in forest – plantation cover, a nation’s resource base would be greatly improved. The international community would benefit from pollution reduction, climate mitigation, and the increased trading opportunities that arise from new income sources.

Conclusion

Despite the recent increase in refinery capacity, Sudan is still an energy importing country and the energy requirements have been supplied through imports that have caused financial problems. Because of the economical problems in the Sudan today, the Sudanese energy policy should concentrate on assurance of energy supply, reliability, domestic sufficiency and renewability. Therefore, biomass, as a renewable energy source, seems interesting (especially fuelwood) because its share of the total energy production at 87% is high and the techniques for converting it to useful energy are easy. On the other hand, biomass may, also, see greatly expanded use in response to the environmental problems caused by fossil fuel use in the country. Hence, bioenergy in general, and biomass particularly, is proposed in this paper to have a central role to play in future, more sustainable energy scenarios. However, for this to become a reality, several real problems need to be overcome. For example, in Sudan, as in other developing countries, modernisation of biomass energy provision is an urgent necessity for the sake of human health, protection of the environment, and climate change abatement. Given sufficient recognition, resources and research bioenergy could become the environmentally friendly fuel of the future. To ensure a better quality of life for all people, now and in the future, through the implementation of sustainable development initiatives that promote: (1) Food and water security (2) Economic efficient that helps to eliminate inequalities (3) Social equity for all, regardless of race, gender, disability or creed (4) Effective education for environmentally and socially responsible citizenship (5) Environment integrity, and environmental justice (6) Democracy, and mutual understanding between people.

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