The IIOAB Journal
SPECIAL ISSUE ON ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE DEVELOPMENT

ISSN: 0976-3104

REVIEW ARTICLE

ENERGY, ENVIRONMENT, AND SUSTAINABLE DEVELOPMENT IN SUDAN

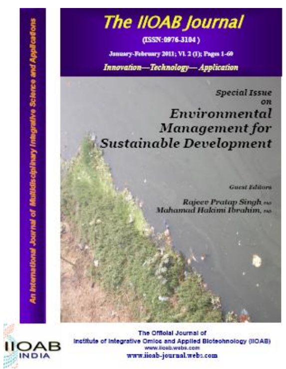
Abdeen Omer[1]

Energy Research Institute (ER), Nottingham NG7 4EU, UK

Received on: 9Th-Aug-2010; **Revised on:** 18th-Oct-2010; **Accepted on:** 5th-Dec-2010; **Published on:** 20thJan-2011.

*Corresponding author: Email: abdeenomer2@yahoo.co.uk Tel: +44-115 9513163; Fax: +44-115 9513159

ABSTRACT



Application of new and renewable sources of energy available in Sudan is now a major issue in the future energy strategic planning for the alternative to the fossil conventional energy to provide part of the local energy demand. Like many of the African leaders in renewable energy utilisation, Sudan has a well-defined commitment to continue research, development, and implementation of new technologies. Sustainable low-carbon energy scenarios for the new century emphasise the untapped potential of renewable resources are needed. Rural areas of Sudan can benefit from this transition. The increased availability of reliable and efficient energy services stimulates new development alternatives. It is concluded that renewable environmentally friendly energy must be encouraged, promoted, implemented, and demonstrated by full-scale plant especially for use in remote rural areas.

.

Keywords: ***Sudan; energy; impacts on environment; sustainable development***

[I] INTRODUCTION

This section is an introduction to the energy problem and the possible savings that can be achieved through improving energy performance and the use of solar energy sources. The relevance and importance of the study is discussed in the section, which, also, highlights the objectives of the study, and the scope of the article. Energy issues affect every aspect of modern society. These issues have been of primary concern, since the second oil crisis and the Gulf War. Energy problems are associated with distribution, access and security of supply. Particularly for the energy-deficient countries and remote islands/areas, renewable energy appears to be sustainable and a clean source of energy derived from nature [1]. The utilisation of available renewable energy sources like solar, wind and biomass energy is of practical importance for future socio-economic development of the country. Sudan is an agricultural country with fertile land, plenty of water resources, livestock, forestry resources and agricultural residues. Energy is one of the key factors for the development of national economies in the Sudan. Energy sources are divided into two main types; conventional energy (woody biomass, petroleum products and electricity); and non-conventional energy (solar, wind, hydro, etc.). Sudan possesses a relatively high abundance of sunshine, solar radiation, moderate wind speeds, hydro and biomass energy resources. Application of the new and renewable sources of energy available in the Sudan is a major issue in the future strategic planning for an alternative to the fossil conventional energy to provide part of the local energy demand. Sudan is an important case study in the context of renewable energy. It has a long history of meeting its energy needs through renewables. Sudan's renewables portfolio is broad and diverse, due in part to the country's wide range of climates and landscapes. Like many of the African leaders in renewable energy utilisation, Sudan has a well-defined commitment to continue research, development and implementation of new technologies.

As for example, ''climate change is a hot issue in world politics''. The use of fossil fuel is seen as a cause of critical global warming. Long-term energy options currently considered include the petroleum, electricity, and biomass. Sustainability is increasingly becoming an element of world politics, although there is not yet agreement on a clear definition and indicators are still not yet fully agreed upon that would effectively enable the establishment of the sustainable development, which is so eagerly sought. However, the snowball is rolling: the process of designing sustainable development has started, and it is only a matter of political will, negotiations and time for it to accelerate, hopefully in the right direction. The job is tough, and the variety of stakeholders involved in today's globalisation process makes the whole story even more interesting and challenging. And yet, globalisation and sustainable development are bound to become tautological. The goal of sustainability has different meanings and measures specific to various regions of the planet, each with

ISSN: 0976-3104

their own economics, histories, and cultures. A pathway to sustainable development that is reasonable, achievable and hence natural in one country. Growing concerns about social and environmental sustainability have led to increased interest in planning for the energy utility sector because of its large resource requirements and production of emissions. A number of conflicting trends combine to make the energy sector a major concern, even though a clear definition of how to measure progress toward sustainability is lacking. These trends include imminent competition in the electricity industry, global climate change, expected long-term growth in population and pressure to balance living standards (including per capital energy consumption). Designing and implementing a sustainable energy sector will be a key element of defining and creating a sustainable society. In the electricity industry, the question of strategic planning for sustainability seems to conflict with the shorter time horizons associated with market forces as deregulation replaces vertical integration.

Sudan is an agricultural country with fertile land, plenty of water resources, livestock, forestry resources, and agricultural residues. Energy is one of the key factors for the development of national economies in Sudan. An overview of the energy situation in Sudan is introduced with reference to the end uses and regional distribution. Energy sources are divided into two main types; conventional energy (woody biomass, petroleum products, and electricity); and non-conventional energy (solar, wind, hydro, etc.). Sudan enjoys a relatively high abundance of sunshine, solar radiation, moderate wind speeds, hydropower, and biomass energy resources. Sudan is an important case study in the context of renewable energy. It has a long history of meeting its energy needs through renewables. Sudan's renewables portfolio is broad and diverse, due in part to the country's wide range of climates and landscapes **[Appendixes-1 and -2]**.

In developed countries, most investments in electricity generation have paid back their initial capital costs. Research and development of new electricity generation technologies are well under way, and these technologies hold good promise of achieving commercial feasibility. New investments in electricity generation have not been aggressively pursued in recent years. Rather, policies for existing energy infrastructures have included improved options for more sustainable electricity generation, e.g., less pollution, higher fuel efficiency and life extension. However, are, at best, only interim solutions. Stakeholders interaction is essential to create a culture of sustainability, with educational, regulatory, economic, environmental and ethical dimensions that can have an impact on society overall. Such a culture of sustainability must be designed, managed and measured in ways compatible with societal attitudes towards risk, including changes in perspective over medium and long-term time horizons. Risk-related concepts play a large part in what technologies the public views as sustainable, whether it concerns potentially large accidents from electric generation technologies, greenhouse gas emissions, vulnerability to natural disasters, or decommissioning and site reclamation problems. Research and development costs and expected lead times related to electricity generation, also play a role in stakeholder positions and public attitudes [2].

There are increasing concerns but the sustainability of the energy sector, ranging from impacts of current operation to the choice of future options for system development. These concerns include such issues as health and safety, environmental emissions, use of energy and materials resources, regulated versus competitive markets, vulnerability of electrical energy networks, cost and equity issues among users of diverse size, and appropriate technology for the development and commercialisation of improved supply and end-use equipment. Such concerns span the geographic spectrum from local issues such as cost and siting, to regional issues like acid rain [3], state and national issues such as deregulation and social acceptance of competing technologies, and global issues such as climate change [4]. Decision-makers and planners in the energy sector must address climate change and global warming issues, and fit them into a broader framework of national and world energy policies. The methodological framework needed to assist decision-makers can be generalised in part, because most of these problems share common elements, and can be characterised by their combination of: (1) Complexity (2) dispersed solutions (3) finite resources, and (4) societal impacts.

The move towards a de-carbonised world, driven partly by climate science and partly by the business opportunities it offers, will need the promotion of environmentally friendly alternatives, if an acceptable stabilisation level of atmospheric carbon dioxide is to be achieved. This requires the harnessing and use of natural resources that produce no air pollution or greenhouse gases and provides comfortable coexistence of human, livestock, and plants. This study reviews the energy-using technologies based on natural resources, which are available to and applicable in the farming industry. Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of CO2 and NOx and CFCs emissions triggered a renewed interest in environmentally friendly cooling, and heating technologies. Under the 1997 Montreal Protocol, governments agreed to phase out chemicals used as refrigerants that have the potential to destroy stratospheric ozone. It was therefore considered desirable to reduce energy consumption and decrease the rate of depletion of world energy reserves and pollution of the environment. In the areas of power systems plan, one of the most pressing problems those exemplifiers this combination of characteristics is the intersection between:

- The rapid liberalisation of energy industries driving short-term actions to maximise stakeholder values, and
- The possible restrictions on greenhouse gas emissions proposed to meet the problem of global climate change.

National Electricity Corporation (NEC) had the goal of improving electricity system planning methodological with

IIOAB ISSN: 0976-3104

regard to sustainability. Within this broad aim, this search has specific goals, including:

- To involve a wide-range of electricity sector participants, including utilities, regulators, environmentalists, and customers.
- To identify and implement a wider range of measures that will be more direct indicators of sustainability than the current response impacts and pollutant outputs.
- To create improved electricity sector modeling tools that simulate electricity system operation under competition, and include transmission and distribution effects more directly into strategic planning.
- To consider technology options beyond the current next generation.
- To increase the comprehensiveness of current life-cycle assessment, by including broader range of technologies, inputs and outputs are sensitive to technology choice versus the state of underlying production and transport infrastructures.
- To improve decision analysis tools to assist stakeholders in reaching consensus on complex alternatives, option portfolios, and flexible contingencies.
- To make the data and models developed for understanding the relationship between power systems and sustainability, available and usable through Internet access.

NEC handled wide variety of electricity generation technologies **[Table-1]**, including:

Thermal (fossil, combined cycle, combustion turbines).
Storage (pumped hydro, batteries, compressed air).
Non-dispatchable technologies (solar, wind, cogeneration, load management).

The data required to perform the trade-off analysis simulation can be classified according to the divisions given in **[Table-2]** the overall system or individual plants, and the existing situation or future development.

Table: 1. Comparison between different energy consumed in Sudan (GWh) [5]

Year	Electricity	Petroleum	Biomass	Renewable Technologies
1975	800	550	3000	50
1980	900	600	3500	60
1985	1200	650	4000	100
1990	1300	700	6000	120
1995	1400	800	7000	150
2000	1500	900	8000	200

1.1. Geographic Profile of the Sudan

This section comprises a comprehensive review of geographical location of the Sudan, energy sources, the environment and sustainable development. It includes the renewable energy technologies, energy efficiency systems, energy conservation scenarios, energy savings and other mitigation measures necessary to reduce climate change. Sudan is the largest country of the African continent, with an area of approximately one million square miles (2.5 x 10^6 km^2). Sudan is a federal republic located in eastern Africa. It extends between latitudes 3º'N and 23º'N, and longitudes 21º 45'E and 39º'E. Sudan is a relatively sparsely populated country. The total population according to the 2009 census was 39 x 10^6 inhabitants. The growth rate is 2.8%/y, and population density is 14 persons per square kilometres. The country is divided into 26 states and a federal district, in which the capital, Khartoum is located. Sudan is known as a country of plentiful water, rich in land, with the highest total and renewable supply of fresh water in the region (eastern Africa). Sudan is considered one of the least developed countries, with a per capita income of less than US $ 400 and a real growth rate of 0.2 % of real gross domestic product (GDP) during the last ten years. However, during 1980s the real growth rate of GDP was negative mainly due to drought and desertification. The backbone of Sudan's economy is its agricultural sector. The agricultural sector determines to a great extent the economic performance of the Sudanese economy. In fact the country can be rescued by proper organisation and utilisation of its agricultural potential. Recent development due to rehabilitation and improvement in the agricultural sector has raised the share to 41% [6].

Table: 2. Classifications of data requirements [7]

	Plant data	System data
Existing data	Size Life Cost (fixed and var Operation and Maintenance) Forced outage Maintenance Efficiency Fuel Emissions	Peak load Load shape Capital costs Fuel costs Depreciation Rate of return Taxes
Future data	All of above, plus Capital costs Construction trajectory Date in service	System lead growth Fuel price growth Fuel import limits Inflation

1.2. Energy Situation in Sudan

Among the renewable energy sources, biomass seems one of the most interesting because of its share of the total energy consumption of the Sudan is high at 87% and the techniques for converting it to useful energy are not necessarily sophisticated. Implementation of biomass-based energy programmes will not, of course, be a definitive solution to the country's energy problem, but it will bring new insight for efficient energy use in the household sector, especially in rural areas where more than 70% of the populations live (25 million). The estimates are based on the recoverable energy potential from the main agricultural residues, livestock farming wastes, forestry and wood processing residues; and municipal wastes.

ISSN: 0976-3104

Fuelwood, animal wastes, agricultural crop residues and logging wastes have been used through direct burning in the Sudan for many years. These sources are often called non-commercial energy sources, but in the 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 at the 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 the meal of meat as a cutlet meatball and meat roasted on a revolving vertical spit.

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 be grouped into two main categories, i.e., forest sources (forests under the control of 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 becomes scarce, which is the case in many parts of the world, the collection time has increased and although men do not perceive it, this has many undesirable consequences, which can be clearly seen in many rural region of the Sudan. Women have less time for their other important functions, such as cooking, washing, water collection and child rearing which may affect the nutrition and health of the entire family. Wood energy is, for many countries, one of the few locally available sources of energy, which they can afford. Its substitution by imported fossil fuels, as has often been carelessly recommended, should attentively be evaluated to avoid undesirable political, economic and social consequences. This will also contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or greenhouse gases. Renewable energy needs, especially in rural areas and small communities. The role of renewable is big in solving essential life problems especially in rural areas for people and their resources development like the availing of energy for the medical services for people and animal, provision of water, education, communication and rural small industries.

[II] ENVIRONMENTAL ASPECTS

Environmental pollution is a major problem facing all nations of the world. People have caused air pollution (since they learned proceeding to use fire), but man-made air pollution anthropogenic air pollution) has rapidly increased since industrialisation began. Many volatile organic compounds and trace metals are emitted into the atmosphere by human activities. The pollutants emitted into the atmosphere do not remain confined to the area near the source of emission or to the local environment, and can be transported over long distances, and create regional and global environmental problems.

A great challenge facing the global community today is to make the industrial economy more like the biosphere, that is, to make it a more closed system. This would save energy, reduce waste and pollution, and reduce costs. In short, it would enhance sustainability. Often, it is technically feasible to recycle waste in one of several different ways. For some wastes there are powerful arguments for incineration with energy recovery, rather than material recycling. Cleaner production approach and pollution control measures are needed in the recycling sector as much as in others. The industrial sector world widely is responsible for about one third of anthropogenic emissions of carbon dioxide, the most important greenhouse gas. Industry is also an important emitter of several other greenhouse gases. And many of industry's products emit greenhouse gases as well, either during use or after they become waste. Opportunities exist for substantial reducing industrial emissions through more efficient production and use of energy. Fuel substitutions, the use of alternative energy technologies, process modification, and by revising materials strategies to make use of less energy and greenhouse gas intensive materials. Industry has an additional role to play through the design of products that use less energy and materials and produce lower greenhouse gas emissions.

Development in the environmental sense is a rather recent concern relating to the need to manage scarce natural resources in a prudent manner-because human welfare ultimately depends on ecological services. The environmental interpretation of sustainability focuses on the overall viability and health of ecological systems- defined in terms of a comprehensive, multiscale, dynamic, hierarchical measure of resilience, vigour and organisation. Natural resource degradation, pollution and loss of biodiversity are detrimental because they increase vulnerability, undermine system health, and reduce resilience. The environmental issues include:

- Global and transnational (climate change, ozone layer depletion).
- Natural habitats (forests and other ecosystems).
- Land (agricultural zones).
- Water resources (river basin, aquifer, water shed).
- Urban-industrial (metropolitan area, air-shed).

Environmental sustainability depends on several factors, including:

- Climate change (magnitude and frequency of shocks).
- Systems vulnerability (extent of impact damage).
- System resilience (ability to recover from impacts).

Economic importance of environmental issue is increasing, and new technologies are expected to reduce pollution derived both from productive processes and products, with costs that are still unknown. This is due to market uncertainty, weak appropriability regime, lack of a dominant design, and difficulties in reconfiguring organisational routines. The degradation of the global environment is one of the most serious energy issues. Various options are proposed and investigated to mitigate climate change, acid rain or other environmental problems. Additionally, the following aspects play a fundamental role in developing environmental technologies, pointing out how technological trajectories depend both on exogenous market conditions and endogenous firm competencies:

(1) Regulations concerning introduction of Zero Emission Vehicles (ZEV), create market demand and business development for new technologies.
(2) Each stage of technology development requires alternative forms of division and coordination of innovative labour, upstream and downstream industries are involved in new forms of inter-firm relationships, causing a reconfiguration of product architectures and reducing effects of path dependency.
(3) Product differentiation increases firm capabilities to plan at the same time technology reduction and customer selection, while meeting requirements concerning network externalities.
(4) It is necessary to find and/or create alternative funding sources for each research, development and design stage of the new technologies.

The Sudan energy consumption is modest by international standards. The energy balance is dominated by biomass. Woody biomass makes up 71 percent, petroleum products 19%, non-woody biomass 8% and hydropower 2% [8]. The total Consumption of the country is as low as 6.3 million tons of oil equivalent (TOE) while the total primary supply is about 11 million TOES. This means that 43% of the energy is lost in converting wood to charcoal. Distances transported nearly always exceed 600 km. The major consumers are households (78% of the total energy). The largest consumers of firewood are brick markers. The efficiency of the traditional charcoal stoves is as low as 16 percent. The forest cover of Sudan receded from 25% in 1956 to 12% in 2001. Sudan is a member of the club of the 18 countries of "Least Forest Covered". Oil fields are in Addar Yale, Bashair and Heglig. Crude from the former two is transported by river barges and trucked respectively.

The environmental impacts of the various processes involved have never been addressed. Further more some of the crude is wastefully used directly as a source of energy. The contribution of the two fields to the GNP has never been disclosed neither have their negative impacts on the environment. The oil is pumped from the various wells and fields through a system of 160 km of pipes the central facility at Heglig. The crude is de-watered at Heglig and then piped 1610 km to the Red Sea export terminal. The infrastructure of the operation includes an extensive network of raised roads and five field facilities. In addition to the central facility at Heglig, there is the airport, the contractors' camp, the newly-founded towns of Heglig and Keilak Al Kharassan, five pumping stations, a metering station at El Obeid, two refineries at El Obeid and Khartoum and the large refinery al El Gaili. Oil is a principal factor in Sudanese politics. It is the government's main source of income and the oil sector is driving economic growth. Meanwhile, the oil industry is poorly managed and highly politicised. Rather than contributing to an environment of peace and equitable development, it remains a source of strife and division.

[III] SUSTAINABILITY

Absolute sustainability of electricity supply is a simple concept: no depletion of world resources and no ongoing accumulation of residues. Relative sustainability is a useful concept in comparing the sustainability of two or more generation technologies. Therefore, only renewables are absolutely sustainable, and nuclear is more sustainable than fossil. However, any discussion about sustainability must not neglect the ability or otherwise of the new technologies to support the satisfactory operation of the electricity supply infrastructure. The electricity supply system has been developed to have a high degree of resilience against the loss of transmission circuits and major generators, as well as unusually large and rapid load changes. It is unlikely that consumers would tolerate any reduction in the quality of the service, even if this were the result of the adoption of otherwise benign generation technologies. Renewables are generally weather-dependent and as such their likely output can be predicted but not controlled. The only control possible is to reduce the output below that available from the resource at any given time. Therefore, to safeguard system stability and security, renewables must be used in conjunction with other, controllable, generation and with large-scale energy storage. There is a substantial cost associated with this provision.

It is useful to codify all aspects of sustainability, thus ensuring that all factors are taken into account for each and every development proposal. Therefore, with the intention of promoting debate, a sustainability matrix is presented **[Table-3]**. The following considerations are proposed:

(1) Long-term availability of the energy source or fuel.
(2) Price stability of energy source or fuel.
(3) Acceptability or otherwise of by-products of the generation process.
(4) Grid services, particularly controllability of real and reactive power output.
(5) Technological stability, likelihood of rapid technical obsolescence.
(6) Knowledge base of applying the technology.
(7) Life of the installation – a dam may last more than 100 years, but a gas turbine probably will not.
(8) Maintenance requirement of the plant.

ISSN: 0976-3104

This article envisages the ways of integrated development of combined heat and power sector in Sudan. However, the assumptions and objectives seem to be applicable to other

Table: 3. Sustainability matrixes [9]

Power categories	1*	2*	3*	4*	5*	6*	7*	8*	9*	Index
Conventional coal fired stream plant	3	1	1	5	1	1	4	3	3	22
Oil fired stream plant	2	1	1	5	3	3	4	3	3	25
Combined cycle gas turbine	2	3	2	4	4	4	4	2	4	29
Micro combined heat and power	2	3	2	4	4	4	3	2	4	29
Nuclear	4	4	3	5	4	4	3	2	3	32
Hydropower	5	5	5	3	5	5	5	4	2	39
Tidal power	5	5	5	2	5	5	5	4	2	38
Onshore wind	5	5	5	2	5	5	4	4	3	38
Offshore wind	5	5	5	2	5	5	3	4	4	38
Land-fill gases	3	5	3	1	3	4	4	3	2	28
Municipal incineration	5	5	4	3	4	4	4	3	4	36
Biomass, field and forest crops plus waste straw	5	5	4	3	4	4	4	3	4	36
Import	1	1	5	1	5	5	5	5	5	33
Hydro pumped storage	-	-	5	5	5	5	5	5	2	32
Electrochemical storage	-	-	4	4	4	4	4	4	5	29
Diesel	2	1	1	1	4	5	3	4	4	25

1* fuel availability, 2* price stability of fuel, 3* by-product acceptability, 4* grid services, 5* technological obsolescence, 6* knowledge base, 7* life of the installation, 8* maintenance requirement, 9* infrastructure requirements.

Table: 4: Effective biomass resource utilisation

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

Table: 5. Agricultural residues routes for development

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

developing countries having plenty of agricultural, forest and animal resources. The process of biomass power generation would certainly reduce dependence on imported fossil fuel and provides a clear indication in reducing the GHG emissions in the environment and it could claim carbon credit more effectively. 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. Also, 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.

Sustainable energy is energy that, in its production or consumption, has minimal negative impacts on human health and the healthy functioning of vital ecological systems, including the global environment. It is an accepted fact that renewable energy is a sustainable form of energy, which has attracted more attention during recent years. A great amount of renewable energy potential, environmental interest, as well as economic consideration of fossil fuel consumption and high emphasis of sustainable development for the future will be needed. Explanations for the use of inefficient agricultural-environmental polices include: the high cost of information required to measure benefits on a site-specific basis, information asymmetries between government agencies and farm decision makers that result in high implementation costs, distribution effects and political considerations [10]. Achieving the aim of agric-environment schemes through:

- Sustain the beauty and diversity of the landscape.
- Improve and extend wildlife habitats.
- Conserve archaeological sites and historic features.
- Improve opportunities for countryside enjoyment.
- Restore neglected land or features, and create new habitats and landscapes.

The data required to perform the trade-off analysis simulation can be classified according to the divisions given in **[Table-4]** the overall system or individual plants, and the existing situation or future development. The effective economic utilisations of these resources are shown in **[Table-5]**, but their use is hindered by many problems such as those related to harvesting, collection, and transportation, besides the photo-sanitary control regulations. Biomass energy is experiencing a surge in interest stemming from a combination of factors, e.g., greater recognition of its current role and future potential contribution as a modern fuel, global environmental benefits, its development and entrepreneurial opportunities, etc. Possible routes of biomass energy development are shown in Table 11. Biomass resources should be divided into residues or dedicated resources, the latter including firewood and charcoal can also be produced from forest residues **[Table-6]**.

Table: 6. Biomass residues and current use

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

Biomass energy includes fuelwood, 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

ISSN: 0976-3104

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%. The main advantages are related to energy, agriculture and environment problems, are foreseeable both at regional level and at worldwide level and can be summarised as follows:

- Development of new know-how and production of technological innovation.
- Reduction of dependence on import of energy and related products.

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, the 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. The aim of any modern biomass energy systems must be:

- To maximise yields with minimum inputs.
- Utilisation and selection of adequate plant materials and processes.
- Optimum use of land, water, and fertiliser.
- Create an adequate infrastructure and strong R and D base.
- Reduction of environmental impact of energy production (greenhouse effect, air pollution, waste degradation).
- 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

[IV] ENVIRONMENTAL POLICIES AND INDUSTRIAL COMPETITIVES

The industrial development strategy in Sudan gives priority to the rehabilitation of the major industrial areas with respect to improvement of infrastructure such as roads, water supply, power supply, sewer systems and other factors. This strategy also takes into consideration the importance of incorporating the

- Substitution of food crops and reduction of food surpluses and of related economic burdens.
- Utilisation of marginal lands and of set aside lands and reduction of related socio-economic and environmental problems (soil erosion, urbanisation, landscape deterioration, etc.).

exploration of how these alternatives are used today and may be used in the future as green energy sources.

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

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.

There is a huge availability of biomass energy resources in Sudan. These resources are scatterly distributed all over the country. In western Sudan, there are briquetting of groundnut shells plants in operation at Nyala and El Obeid. In central Sudan, briquetting plants of cotton stalk installed at Wad El Shafie. In southern Sudan, biogas plants in operation using water hyacinth. Sugarcane bagasse and sugarcane trash already provide a significant amount of biomass for electricity generation. It is known that sugarcane is a perennial crop and sugarcane bagasse available in a particular period of the year. The bagasse-gasifier plants in Kenana are used as standby or at the peak times or if there is any problem in main grid. environmental dimension into economic development plans. However, the relationship between environmental policies and industrial competitiveness has not been adequately examined. For the near future, the real issue concerns the effectiveness of environmental expenditures in terms of reduction of pollution emissions per unit of output. A number of issues relevant to this central concern are presented as follows:

ISSN: 0976-3104

4.1. Implementing ecologically sustainable industrial development strategies

The United Nations Industrial Development Organisation (UNIDO) Agenda 21, (1997), Vienna for achieving sustainable development in the 21st century calls on governments to adopt National Strategies (NS) for sustainable development that ''build on and harmonise the various sectoral, social and environmental policies that are operating in the country'' [4]. NS focuses almost exclusively on development issues and does not integrate industrial and environmental concerns. It does not consider industrial specific environmental objectives or time frames for achieving them. Moreover, it does not specify how specific industrial sub-sectors and plants will meet environmental objectives. Finally, it is formulated with minimal involvement of industrial institutions and private sector associations. To bring together industrial development and environmental objectives it is necessary to:

- Establish environmental goals and action plans for the industrial sector.
- Develop an appropriate mix of policy instruments that support the goals of those plans.
- Design appropriate monitoring and enforcement measurements to realise those goals.

4.2. Applying cleaner Production processes and techniques

Traditional approaches to pollution reduction have been based on the application of end of pipe technologies in order to meet discharge standards. However, the growing recognition that reduction at source is a potentially more cost effective method of abatement is resulting in replacing end of pipe technologies with cleaner production processes. Major constraints in adopting cleaner production methods relate to:

- Lack of awareness about the environmental and financial benefits of cleaner production activities.
- Lack of information about techniques and technologies.
- Inadequate financial resources to purchase imported technologies.

A coordinated effect by industry, government and international organisations can go a long way in overcoming these constraints. In this context key questions that need to be addressed are as follows:

(a) Need for local capacity building, information dissemination, training and education.
(b) Need for sub-sectoral demonstration projects.
(c) Need for increased cooperation with environmental market sectors in developed countries.
(d) Need for life cycle analysis and research on environmentally compatible products.

4.3. Implementing environmental management systems

Environmental management systems (EMSs) are necessary to enable plant to achieve and demonstrate sound environmental performance by controlling the environmental impact of their activities, products and services. The basic tools to ensure compliance with national and/or international requirements and continually improve its environmental performance include:

- Environmental auditing.
- Environmental reporting, and
- Environmental impact assessments.

In addition, the adoption of EMS may require extensive training of corporate staff. A practical and effective means of doing this is through the design and support of joint capacity strengthening programmes by industry association and bilateral and multilateral agencies.

4.4. Managing and conserving water resources

It is estimated that by year 2025, there will be a global crisis in water resources. Accelerated growth of industry will lead to increase in industrial water use. Moreover, major industrial water pollutant load is expected to increase considerably in the near future. Therefore, to better manage water resources by industry, there is a real need for integrating demand trend and use patterns. The main elements of an industrial management strategy can be identified as follows:

- Analytical services.
- Promotional services.
- Services for the development of industry and water supply infrastructure.

4.5. Using market based instruments (MBIs) to internalise environmental costs

As complements to command and control measures for resource conservation and pollution prevention in industry. MBIs represent a useful and efficient cost effective policy measures that internalise environmental costs. A plant's decision to invest in clean production depends primarily on the following factors:

(a) Relative costs of pollution control in overall production costs.
(b) Price elasticities of supply and demand for intermediary and final goods, and
(c) Competitive position of plant in a particular industrial sector.

4.6.Counteracting threats from eco-labelling requirements

The increasing export orientation of production makes it necessary to maintain competitive position in world markets. The emergence of a wide variety of eco-labelling requirements and

ISSN: 0976-3104

lack of timely information on multitude of scheme may adversely affect certain export sectors. Needed initiatives to counteracting perceived threats could be presented as follows:

- Information dissemination.
- Life cycle analysis.
- Establishing certification centres.
- Infrastructure support.

4.7. Implementing the United Nations (UN) framework convention on climate change

The UN climate change convention entered into force on 21st March 1994. The convention objective is the stabilisation of greenhouse gas concentration in the atmosphere at safe levels. For industry, responding to this convention will undoubtedly be a major challenge. Industry will be directly affected. Sudan as party to this convention is obliged to take a number of actions and cooperates effectively in order to meet this challenge. Sudan has to contribute to the common goal of reducing greenhouse gases emissions by taking precautionary measures to mitigate causes and anticipate impacts of climate change. However, there may not be adequate means to do so, and Sudan will therefore require international assistance. The main requirements are:

- Access to best energy-efficient technologies available on the world market, where such technologies are relevant to our natural resources endowments, our industrial requirements and are cost effective.
- Building an energy-efficient capital stock by accelerating the development of low energy intensity processes and equipment.
- Strengthening national capabilities for energy-efficient design and manufacturing.

Areas where technical expertise to implement the convention is necessary include:

- Preparing national communications on greenhouse gas emissions. The communications are supported to contain an assessment of the magnitudes and sources of greenhouse gases as well as identification of reduction methods.
- Supporting technology transfer for improvement in the efficiency of fuel based power generation.
- Promotion technology transfer for the use of renewable sources of energy such as biomass, wind, solar, hydro, etc.
- Developing and implementing technology transfer for energy efficiency programmes in industry, in complementarities with cleaner production/pollution prevention measures.
- Analysing the impact of climate change response measures on the economic and industrial development of the country, with the view to identifying economically viable technology options for reducing greenhouse gas emissions from the production and consumption of energy.

4.8. Addressing concerns of small and medium scale industry (SMI)

Small and medium scale enterprises not only contribute to productivity growth and employment but are also important as collective sources of localised pollution loading such as organic wastes in water effluent, as well as hazardous wastes, heavy metal sludge, solvents, waste oils, acidic and alkaline wastes, photo wastes, etc. Often, these wastes are disposed of in unsafe manure and are extremely difficult to monitor. The cost of control in relation to output is too high, so even a modest increase in the costs (of environmental regulations) may threaten prevention and control may be well known and easily available, there is no guarantee that they will be adopted. Moreover, even when policy measures are in place, their enforcement and monitoring is a real problem for SMI sector on account of their large numbers and diversity. It is clear that environment problems of SMIs require special attention and special measures to address their particular problems.

[V] ENERGY AND ENVIRONMENT

5.1. Petroleum industry pollution and greenhouse gases emissions in Sudan

The activities of oil exploration in Sudan began in late 1950s in the coastal areas of Red Sea. The results of exploration indicated that there is considerable amount of natural and liquefied gases in Suwakin and Bashair, and the quantities were estimated between 45-326 $\times 10^9$ cubic meters [12]. According to the increasing oil industry activities in Sudan such as production, refining and export/consumption, and if we consider the entire fuel cycle, namely: exploration, extraction, preparation/transformation, transportation, storage, pollution, including the increase in greenhouse gases, as result of petroleum industry will be very significant in the forthcoming future. Exploitation has started in the south of Sudan and exports have begun recently. In the year 2005 about 2×10^9 tonnes of petroleum products were burnt in Sudan [11]. This amount will be doubled in the year 2010. There is a shortage of information concerning the area of greenhouse gases recording in Sudan.

5.2. Privatisation and price liberalisation in energy source supplies

The privatisation and price liberalisation in energy fields has to some secured (but not fully). Availability and adequate energy supplies to the major productive sectors. The result is that, the present situation of energy supplies is for better than ten years ago. The investment law has also encourage the participation of the investors from the national level as well as from the international friendly and sisters' countries to invest in energy sources supply such as:

ISSN: 0976-3104

- Petroleum products (import in particular) in the northern states.
- Electricity generation (in some states) through providing large diesel engine units.

The readily implementation of electricity price liberalisation has some extent release the National Electricity Corporation (NEC) from the heavy dependency of government subsidies, and a noticeable improved of NEC management, and electricity supplies are achieved.

5.3. *Synthesis of the renewable energy*

Although the overall impact of renewables has been unnecessary 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 **[Table-7]**.

5.4. *Geothermal energy*

The use of geothermal energy in Sudan has the following special characteristics:

Disadvantages are geothermal energy is a low-temperature resource tied to specific locations and can be used only in specific types of system and minerals in some thermal waters can produce scaling problems that increase costs. Advantages:

- Sudan has a big geothermal energy potential and geothermal energy can be environmentally sound if wastewater or brine is properly disposed of (e.g., by reinjection) and there is no air pollution.
- The dependency on imported energy sources could be decreased.
- The number of jobs can be increased.
- Competitiveness of geothermal energy should increase owing to projected increases in domestic prices of competing fossil fuels.
- Geothermal wells do not give low temperature heat; certainly they give much higher than solar flat plate collectors.

Not only does cost of the fuel drive the researcher to explore an alternative source of energy, but ozone layer problems are other factor that should be considered in searching for cheap and clean energy sources **[Table-8]**. Solar energy is an unlimited, cheap and clean source of energy, which has been utilised to replace conventional energy, but there still is a need to develop a technology to utilise the solar energy. Nowadays, solar energy is widely used in heating water, dehumidifying air and generating electrical energy for many domestic, agricultural and industrial applications. For these applications, the most important piece of the system equipment is the solar collector in which solar energy is converted into heat or electrical power. Although there are several designs for solar energy collecting devices, flat-plate collectors are the most common and popular type. They have the advantages of being simple to build, employing locally available materials, they are easy to operate and maintain, they have the ability to function even during cloudy or hazy days with diffuse solar radiation only, and they are capable of integration into a roof or a wall structure.

Fresh water supply is one of the most limiting conditions for the populations of arid regions. Following methods can solve the problem of providing arid areas with fresh water:

(1) Transportation of water from other locations.
(2) Desalination of saline water (ground and underground).
(3) Extraction of water from atmospheric air.

Transportation of water through these regions is usually very expensive, and desalination depends on the presence of saline water resources, which are usually rare in arid regions. The extraction of water from atmospheric air can be accomplished by two methods: cooling moist air, and absorbing water vapour from moist air using a solid or a liquid desiccant, with subsequent recovery for the extracted water by heating the desiccant and condensing the evaporated water. The significant increase in recent years of the number of rural electrification systems, using photovoltaic technology for illumination or water pumping in order to reduce the burden of capital costs per unit of generated power.

The power generation and supply for isolated areas can be effectively achieved using wind energy as the principle energy source. The savings are not only economic but also environmentally sound. However, the transient nature of the energy supply that is delivered to the power system from wind-turbine poses significant challenges to the design and control of the system. The efficiency of such systems can only improve with more effective control and a better understanding of the characteristics of these types of systems.

ISSN: 0976-3104

Table: 7. Diversity of promotion strategies [12]

Technology	Strategy	Key change agents	Mechanisms
Power generation			
Wind	Government-enabled market pull	Private sector State utilities Manufacturers	Fiscal incentives Multilateral finance
Small-hydro	Government-enabled market pull	Private sector State utilities Manufacturers	Fiscal incentives Multilateral finance
Biomass cogeneration	Government-enabled market pull	Private sector Government	Fiscal incentives Low interest finance
Solar PV	Combination of demonstration and pull	NGOs Intermediaries Manufacturers	Flexible loan serving Maintenance by intermediaries
Thermal energy			
Biogas	Technology push	Government NGOs Turnkey workers	Cash subsidy Training support
Improved stoves	Technology push	Government NGOs Self-employed workers	Cash subsidy Training support
Solar cookers	Push in the beginning Currently market pull	Government Manufacturers	Mini-subsidy Segmentation with focus On small towns and cities
Solar water heaters	Push in the beginning Currently market pull	Government Manufacturers	Segmentation with focus on industrial systems

Considering energy crises and pollution problems today, investigations have been concentrated on decreasing fuel consumption by using alternative fuels and lowering the concentration of toxic components in combustion products. Hydrogen is considered as a renewable clean energy source. Two methods using hydrogen in spark ignition engines were investigated in Sudan. The first method is to mix hydrogen with gasoline. The second concerns using hydrogen as a standard fuel. The advantage of the hydrogen-supplemented fuel is that it requires a smaller quantity of hydrogen, which considerably reduces the problems connected with hydrogen storage in the automobile. A hydrogen-gasoline fuelled engine generally develops lower maximum power and higher NO_x emission compared to an equivalent gasoline engine. Hydrogen can be used as a supplementary fuel in modern spark ignition engines without major changes and it can help save a considerable part of the available oil and save our environment from toxic pollutants.

Depletion of fossil fuels and fluctuating prices has rekindled an interest in the development of renewable fuels/energy sources such as biomass. There is a critical need for development of alternative, appropriate, affordable methods of cooking for use in Sudan. Population pressures on remaining forest resources have resulted in shortages of fuel available for household use and yielded adverse environmental effects. Solar cooker use has the potential to alleviate both problems by reducing dependence on wood as a cooking fuel. However, to gain acceptance and motivate use, there is a need to develop many different solar cooker designs. Each design needs to be suited to specific climates, customers and economic factors. The development requires a good fundamental understanding of the relationship between key design variables and performance. The most commonly used type of solar cooker is the box type. Box type cookers depend on heat retention. They are slow to heat up, but work well even where there is diffuse radiation, convective heat loss caused by wind, intermittent cloud cover, and low ambient temperatures. Despite the variation in approach flat plate, concentrating, and box type) and large variety of inventions and products, the total potential design space is largely unexplored. Systematic examination of the design space requires either extensive testing or models with broad predictive capacity.

The availability of methane and/or natural gas has lead to a worldwide spread of internal combustion engines running on the dual fuel concept. Gaseous fuels also promise to be suitable for higher compression engine

Since it is known that they resist knock more than conventional liquid fuels, as well as producing less polluting exhaust gases, if appropriate conditions are satisfied for its mixing and combustion. Therefore, it is more economical and of environmental advantage to use natural gases in diesel engines, which use the dual fuel concept.

5.5. *Climate change, global warming and the enhanced greenhouse effect*

Changes in the global climate (mean temperature, precipitation, etc.) could also threaten stability of a range of critical interlinked physical, ecological and social systems and subsystems [13]. An important social principle is that the climate change should not be allowed to worsen existing inequities- although climate change policy cannot be expected to address all prevailing equity issues. Some special aspects include:

- The establishment of an equitable and participative global framework for making and implementing collective decisions about climate change.
- Reducing the potential for social disruption and conflicts arising from climate change impacts.
- Protection of threatened cultures and preservation of cultural diversity.

Climate change is one of the most serious concerns of our society. The gases causing the greenhouse effect are carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, troposphere ozone, and stratospheric water vapour. Carbon dioxide is an important greenhouse gas and a major agent of climate change and the most significant greenhouse gas contributing about half of the total greenhouse effect [14]. The recent concentration of atmospheric CO_2 is 25% higher than the pre-industrial level [15]. This increase is primarily due to fossil fuel combustion and deforestation.

Table: 8. Correlation of solar radiation with other weather parameters in Sudan (Yearly averages) [16]

Station	Mean temp. (ºC)	Sunshine duration (h)	Solar radiation (MJm^{-2} day^{-1})	Wind velocity (ms^{-1})
Port Sudan	28.4	9.0	20.87	5.1
Shambat	29.7	9.9	22.82	4.5
Wadi Medani	28.4	9.8	22.84	4.5
El Fasher	25.8	9.6	22.80	3.4
Abu Na'ama	28.2	8.8	21.90	3.1
Ghazala Gawazat	27.2	9.3	21.72	3.0
Malakal	27.9	7.8	19.90	2.8
Juba	27.6	7.8	19.59	1.5
Dongola	27.2	10.5	24.06	4.6
Toker	28.8	7.3	17.60	4.1
Hudeiba	29.3	10.0	22.37	4.0
Aroma	29.1	9.6	21.40	4.2
El Showak	26.3	9.7	22.90	4.1
Zalingei	24.5	8.8	22.98	2.7
Babanusa	28.2	8.9	21.73	2.8
Kadugli	27.5	8.5	21.30	2.7

Climate change might pose a serious threat to our ecological and socio-economic systems, unless measures are investigated to mitigate the rising accumulation of atmospheric CO_2. Green-space in urban ecosystems can reduce atmospheric C levels in three ways. Here, green-space is defined as soil surface area capable of supporting vegetation and the vegetation being supported. First, urban trees and shrubs directly sequester and accumulate atmospheric C in the process of their growth through photosynthesis. Second, urban vegetation decreases building cooling demand by shading and evapotranspiration, and heating demand by wind speed reduction, thereby reducing C emissions associated with fossil fuel use. Third, urban soils store organic C from litter-fall, until it is returned to the atmosphere by decomposition. On the other hand, buildings, factories, and automobiles in urban landscapes release C through fossil fuel consumption.

Industry's use of fossil fuels has been blamed for our warming climate, when coal, gas and oil are burnt, they release harmful gases, which trap heat in the atmosphere and cause global warming. However, there has been an ongoing debate on this subject, as scientists have struggled to distinguish between changes, which are human induced, and those, which could be put down to natural climate variability. Industrialised countries have the highest emission levels, and must shoulder the greatest responsibility for global warming. But action must also be taken by developing countries to avoid future increases in emission levels as their economies develop and population grows. Human activities that emit carbon dioxide (CO_2), the most significant contributor to potential climate change, occur primarily from fossil fuel production. Consequently, efforts to control CO_2 emissions could have serious, negative consequences for economic growth, employment, investment, trade and the standard living of individuals everywhere. Scientifically, it is difficult to predict the relation between global temperature and greenhouse gas concentrations. The climate system contains many processes that will change if warming occurs. Critical processes include heat transfer by winds and currents, the hydrological cycle involving evaporation, precipitation, runoff and groundwater, and the formation of clouds, snow, and ice, all of which display enormous natural variability. The equipment and infrastructure for energy supply and use are designed with long lifetimes, and the premature turnover of capital stock involves significant costs. Economic benefits occur if capital stock is replaced with more efficient equipment in step with its normal replacement cycle, and if opportunities to reduce future emissions are taken in the world they should be less costly. Such flexible approaches would allow society to take account of evolving scientific and technological knowledge, and to gain experience in designing policies to address climate change. Focusing only on CO_2 emissions neglects the full richness of the environmental data, but has been done for several reasons:

- CO_2 is an important global environmental indicator.
- CO_2 emissions can show very significant increases, as Sudan currently produces very little CO_2 from the electricity sector.
- CO_2 and other air pollutants are linked together to new generation capacity; So CO_2 serves as a surrogate for most other emissions.

The environmental characteristics of products have become increasingly important to consumers [17-18]. Firms have responded by placing eco-labels on products that highlight the item's environmental attributes and by introducing new, or redesigned green products [19]. Governments and non-governmental organisations have also responded by organising, implementing, and verifying eco-labelling programmes that

ISSN: 0976-3104

cover thousands of products, which international efforts to standardise environmental labelling schemes have also emerged. From a policy perspective, one aim of eco-labels is to educate consumers about the environmental impacts of the product's manufacture, use, and disposal, thereby leading to a change in purchasing behaviour and ultimately, to a reduction in negative impacts. Further, eco-labelling policies may promote environmental objectives without production site command and control methods and are seen a way of meeting global environmental objectives while complying with international trade agreements. Recent techniques for economically valuing environmental impacts:

- Effect on production.
- Effect on health.
- Defensive or preventive costs.
- Replacement cost and shadow projects.
- Travel cost.
- Property value.
- Wage differences (the wage differential method attempts to relate changes in the wage rate to environmental conditions, after accounting for the effects of all factors other than environment (e.g., age, skill level, job responsibility, etc.) that might influence wages).

5.6. 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. Agriculture determines for the last 30 years the degree of performance growth of the national economy.

5.6.1. Agriculture sector

During the last decades agriculture contributed by about 41% to the Sudan GNP. This share remained stable until 1984-1985 when Sudan was seriously hit by drought and desertification, which led to food shortages, deforestation, and also, by socio-economic effects caused the imposed civil war. The result dropped the agriculture share to about 37%. Recent development due rehabilitation and improvement in agricultural sector in 1994 has raised the share 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 consumed 2.5% of the total energy consumption (28% from electricity, 14.8% from fossil fuels, and the rest from biomass fuels) [20].

5.6.1. 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 follows: 55% from petroleum products, 13% from biomass and 32% from electricity [20].

5.6.3. Domestic use

Household is the major energy consumer. It consumed 92% of the total biomass consumption in form of firewood and charcoal. From electricity this sector consumed 60% of the total consumption, and 5.5% of petroleum products.

5.6.4. Transport sector

The transportation sector (railways, ships, boats, etc.) was not being efficient for the last two decades because of serious damage happened to its infrastructure (roads, workshops, and maintenance centres, etc.). It consumed 10% of the total energy consumption and utilized 60% of the total petroleum products supplied.

Sudan is an energy importing country and the energy requirements has been supplied through imports that have caused financial problems. Because of the economical problems in Sudan today, the Sudanese energy policy should be concentrated on assurance of energy supply, reliability, domestic sufficiency, in time, in economic terms, and renewability. Therefore as a renewable energy source, biomass (especially fuelwood) seems interesting 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, however, see greatly expanded use in response to the environmental problems caused by fossil fuel use in the country. Biomass has been proposed to have a central role to play in future, more sustainable energy scenarios. For this to become a reality several real problems need to be overcome. 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 biomass could become the environmentally friendly fuel of the future.

[VI] DISCUSSION

There is strong scientific evidence that the average temperature of the earth's surface is rising. This was a result of the increased concentration of carbon dioxide (CO_2), and other greenhouse gases (GHGs) in the atmosphere as released by burning fossil fuels [21]. This global warming will eventually lead to substantial changes in the world's climate, which will, in turn, have a major impact on human life and the environment [22]. 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 this 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

ISSN: 0976-3104

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, the 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. The non-technical issues, which have recently gained attention, include: (1) Environmental and ecological factors e.g., carbon sequestration, reforestation and revegetation. (2) Renewables as a CO_2 neutral replacement for fossil fuels. (3) Greater recognition of the importance of renewable energy, particularly modern biomass energy carriers, at the policy and planning levels. (4) Greater recognition of the difficulties of gathering good and reliable biomass energy data, and efforts to improve it. (5) Studies on the detrimental health efforts of biomass energy particularly from traditional energy users. This study discusses a comprehensive review of biomass energy sources, environment and sustainable development. This includes all the biomass energy technologies, energy efficiency systems, energy conservation scenarios, energy savings and other mitigation measures necessary to reduce climate change.

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. Biomass energy supply in Sudan contributed 87% of total energy supply since 1980's. The basic form of biomass comes mainly from firewood, charcoal and crop residues. Out of total fuel wood and charcoal supplies 92% was consumed in household sector with most of firewood consumption in the rural areas [23]. 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 renewable energy sources have significant potential in the fight against climate change.

There is an unmistakable link between energy and sustainable human development. Energy is not an end in itself, but an essential tool to facilitate social and economic activities. Thus, the lack of available energy services correlates closely with many challenges of sustainable development, such as poverty alleviation, the advancement of women, protection of the environment, and jobs creation. Emphasis on institution-building and enhanced policy dialogue is necessary to create the social, economic, and politically enabling conditions for a transition to a more sustainable future. On the other hand, biomass energy technologies are a promising option, with a potentially large impact for Sudan as with other developing countries, where the current levels of energy services are low. Biomass accounts for about one third of all energy in developing countries as a whole, and nearly 96% in some of least developed countries. The convention on Biological Diversity set conservation of biodiversity on the world agenda. Gaps in knowledge need to be addressed for actions to be effective and sustainable. Gaps include: species diversity, microorganisms and their ecological roles, ecological and geographical status of species, human capacity to access and forecast bio-ecological degradation. Requirements for global inventories call for worldwide collaboration. Criteria for setting priorities need to be formulated and agreed. Global inventorying needs a collaborative international effort, perhaps under the aegis of the Convention on Biological Diversity. The recently formulated global taxonomy initiatives are a step in the right direction.

This article envisages the ways of integrated development of combined heat and power sector in Sudan. However, the assumptions and objectives seem to be applicable to other developing countries having plenty of agricultural, forest and animal resources. The process of biomass power generation would certainly reduce dependence on imported fossil fuel and provides a clear indication in reducing the GHG emissions in the environment and it could claim carbon credit more effectively. 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^oC and domestic hot water (DHW) can be supplied with a temperature of 55^oC using energy sources that are most efficient when producing low temperature levels ($<95^oC$) 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^oC 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. Also, 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.

Sustainable energy is energy that, in its production or consumption, has minimal negative impacts on human health and the healthy functioning of vital ecological systems, including the global environment. It is an accepted fact that renewable energy is a sustainable form of energy, which has attracted more attention during recent years. A great amount of renewable energy potential, environmental interest, as well as economic consideration of fossil fuel consumption and high emphasis of sustainable development for the future will be needed. Explanations for the use of inefficient agricultural-environmental polices include: the high cost of information required to measure benefits on a site-specific basis, information asymmetries between government agencies and farm decision makers that result in high implementation costs, distribution effects and political considerations [24]. Achieving the aim of agric-environment schemes through:

- Sustain the beauty and diversity of the landscape.
- Improve and extend wildlife habitats.
- Conserve archaeological sites and historic features.
- Improve opportunities for countryside enjoyment.
- Restore neglected land or features, and create new habitats and landscapes.

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.

There is a huge availability of biomass energy resources in Sudan. These resources are scatterly distributed all over the country. In western Sudan, there are briquetting of groundnut shells plants in operation at Nyala and El Obeid. In central Sudan, briquetting plants of cotton stalk installed at Wad El Shafie. In southern Sudan, biogas plants in operation using water hyacinth. Sugarcane bagasse and sugarcane trash already provide a significant amount of biomass for electricity generation. It is known that sugarcane is a perennial crop and sugarcane bagasse available in a particular period of the year. The bagasse-gasifier plants in Kenana are used as standby or at the peak times or if there is any problem in main grid.

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 be grouped into two main categories, i.e., forest sources (forests under the control of 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 becomes scarce, which is the case in many parts of the world, the collection time has increased and although men do not perceive it, this has many undesirable consequences, which can be clearly seen in many rural region of Sudan. Women have less time for their other important functions, such as cooking, washing, water collection and child rearing which may affect the nutrition and health of the entire family. Wood energy is, for many countries, one of the few locally available sources of energy, which they can afford. Its substitution by imported fossil fuels, as has often been carelessly recommended, should attentively be evaluated to avoid undesirable political, economic and social consequences. This will also contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or greenhouse gases. Renewable energy is needed, especially in rural areas and small communities. The role of renewable is big in solving essential life problems especially in rural areas for people and their resources development like the availing of energy for the medical services for people and animal, provision of water, education, communication and rural small industries.

Mitigation measures that could be under taken to influence the effect of oil industry and use that may contribute in decreasing greenhouse gases (GHGs) emissions 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.

ISSN: 0976-3104

- Controlling GHGs emission detection techniques in oil production, transportation and refining processes in Sudan.
- 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 and supporting environmental and pollution control activities within the Ministry of Energy and Mining (MEM) to effectively cope with the evolving oil industry in Sudan.

6.1. Oil production

Oil was discovered in Sudan in the mid-1970s, but production did not start until 1999. The pioneer companies Chevron and Shell were forced to bow out in 1984, after the outbreak of civil war. They eventually sold their rights in 1990, booking a $1 billion loss. Oil in Sudan accounts for 92.6% of the country's export revenues and with most of its producing oilfields located in the South of the country, the management of the oil industry is a key factor that will determine the future of the country. The oil industry is poorly supervised and highly politicised, and as such, rather than contributing to an enabling environment for peace and equitable development, a source of strife and division **[Figure -1]**.

The focus for 2007 is on both exploration and development. The operators of the producing blocks are implementing aggressive exploration programmes **[Table-9]**. With the companies wanting to achieve payback as quickly as possible, development of discoveries is likely to be prompt.

Table: 9. Sudan's oil reserves [27]

Year	Proven reserves (bln bbl)	Oil production (10^3 bbl/d)
1981	0.2	0.0
1991	0.3	0.0
2001	0.7	211
2005	6.4	355
2006	6.4	397

Refineries:

- Khartoum (50/50 joint venture between the Sudanese government and the CNPC, capacity of (100,000 bbl/d).
- Port Sudan Refinery (21,700 bbl/d).
- Petronas has agreed to joint venture with the Sudanese government to build a new refinery in Port Sudan with capacity of (100,000 bbl/d) to treat Dar Blend crude; to be operational in 2010.
- The small top-up refinery in Abu Gabra is planned for closure 2010. There are plans to build a refinery in Kosti Sudan's oil production will probably in 2010, but revenues may be maintained for another ten years at current levels, depending on the development of oil prices and whether the Dar Blend refinery will indeed be a price booster.

Oil is a principal factor in Sudanese politics. It is the government's main source of income and the oil sector is driving economic growth. Meanwhile, the oil industry is poorly managed and highly politicised. Rather than contributing to an environment of peace and equitable development, it remains a source of strife and division [25].

The Sudanese oil industry is exceptionally profitable because oil companies are exempted from paying taxes in Sudan. These conditions may have been quite reasonable in 1997.

The main Sudanese oil contracts were negotiated in the 1990s, when oil was being traded for less than $20 per barrel and the Sudanese governments had to offer lucrative conditions to attract investments. It makes a big difference, however, whether the companies' share of 20% to 40% of the Profit Oil is sold at $20 or $60 per barrel. Oil is now traded at $90 per barrel and more, boosting profits for the companies and leaving the government of the Sudan with too small a share.

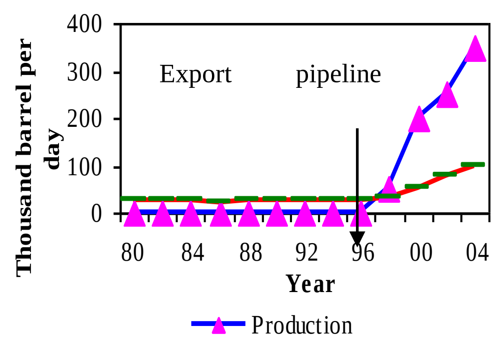


Fig: 1. Sudan's oil production and consumption 1980-2005 [26]

6.2. Sudan's experience in renewable energy technologies

In Sudan, great attention is given to the utilisation of the renewable, and the overall renewable energy potential of the country. Three distinct groups contribute to research, development and utilisation of the resources. These are:
1. Research institutes.
2. Universities, and
3. Private-sector.

Participation and roles in technology diffuse:

1. Government:

- Improved economic competitiveness of technology.
- Support information flow technical financial viability, and resource assessment.
- Support training.
- Undertake R&D.

2. NGOs:

- Training.
- Extension.
- Assessment of local needs.
- Demonstration.
- Promotion of small-scale production.

3. Private-Sector:

- Production.
- Assembly, maintenance and spare-parts supply.
- Marketing.

6.3. Policy development

The non-technical issues, which have recently gained attention include:

- Environmental and ecological factors e.g., carbon sequestration, reforestation and revegetation.
- Biomass as CO_2 neutral replacement for fossil fuels.
- Greater recognition of the importance of renewable energy, particularly modern biomass energy carriers, at the policy and planning levels.
- Greater recognition of the difficulties of gathering good and reliable renewable energy data, and efforts to improve it.
- Studies on the detrimental health efforts of renewable energy particularly from traditional energy users.
- Greater awareness of the need to internalise the externality cost of conventional energy carriers to place them on more equal terms with alternative energy sources.

6.4. The future

(1) In the most of the developing countries, the governments acknowledge that, renewable energy can resolve many pressing problems. Yet, the matter stops at this level ‘‘Acknowledgement’’. Much more is needed, like laws regulating and encouraging business, tax concessions, both to investors and customers, and most of all, a sustained, coordinated and well-planned official publicity campaign to enlight, inform and educate the public at a large.
(2) To avoid the problems of fuel altogether (uncertain availability and skyrocketing prices), and minimise spare-parts, solar and wind pumps are proposed to replace diesel engines in the predominant irrigation areas.
(3) Local manufacture, whenever possible, is to be emphasised to avail renewable energy devices since limited funds are the main constraints in commercialisation and dissemination of the technology. Low cost devices as well as reliable devices have to be provided.
(4) Embarking on conservation energy and reduction of pollution of environment to be undertaken without delay:

- To save on fossil fuel for premium users/export.
- To accelerate development of new and/or remote lands otherwise deprived of conventional energy sources.
- As a preventive measure against shortage of future energy supply against prospective national energy demand.

(5) Launching of public awareness campaigns among investor’s particularly small-scale entrepreneurs and end users of renewable energy technologies to highlight the importance and benefits of renewables.
(6) To direct Sudan resources away from feeding wars and the arms industry towards real development, this will serve the noble ends of peace and progress.
(7) The energy crisis is a national issue and not only a concern of the energy sector, and the country has to learn to live with the crisis for a long period, and develop policies, institutions and manpower for longer term, more effective solutions.
(8) To invest in research and development through the existing specialised bodies e.g., Energy Research Institute (ERI).
(9) To encourage co-operation between nations, a fact this will be much easier in this era of information and the communications revolution.
(10) Government should give incentives to encourage the household sector to use renewable energy technologies instead of conventional energy.
(11) Promotion research and development, demonstration and adaptation of renewable energy resources (solar, wind, biomass, and mini-hydro, etc.) amongst national, regional, and international organisations which seek clean, safe, and abundant energy sources.
(12) Execute joint investments between the private sector and the financing entities to disseminate the renewables with technical support from the research and development entities.
(13) Promotion the general acceptance of renewable energy strategies by supporting comprehensive economic energy analysis taking account of environmental benefit.
(14) Availing of training opportunities to personnel at different levels in donor countries and other developing countries to make use of their wide experience in application and commercialisation of renewable energy technologies.
(15) To encourage the private sector to assemble, install, repair and manufacture renewable energy devices via investment encouragement, more flexible licensing procedures.

[VII] CONCLUSIONS

Sudan as an agricultural country has a good rational of energy from agricultural residues, forestry resources, and animal wastes. Sudan has an excellent annual mean solar radiation of 5.44 kW h m^{-2} day^{-1} which could be of strategic important in substituting for oil, electricity, wood and charcoal; in assisting in rural development, and in improving the quality of life in rural areas. Sudan is rich in wind; about 50% of Sudan's area is suitable for generating electricity (annual average wind speed more than 5 ms^{-1}), and 75% of Sudan's area is suitable for pumping water (annual average wind speed 3-5 ms^{-1}). Production of bio-fuels such as ethanol from sugar cane, takes advantages of year-round cultivation potential in a tropical country like Sudan. Benefits extend from local to regional to national to global. Local rural economies benefit through new economic opportunities and employment in the agricultural sector. Urban regions benefit through cleaner air and health improvements. The nation benefits through substituting domestic resources for costly imported gasoline. The world benefits from reduced CO_2 emissions.

In a country with a population dense, there are extreme pressures on energy and waste systems, which can stunt the country's economic growth. However, Sudan has recognised the potential to alleviate some of these problems by promoting renewable energy and utilising its vast and diverse climate, landscape, and resources, and by coupling its solutions for waste disposal with its solutions for energy production. Thus, Sudan may stand at the forefront of the global renewable energy community, and presents an example of how non-conventional energy strategies may be implemented.

Air pollution from motor vehicles, electricity generation plants, industry, and other sources, natural and man-made, can harm human health, injure crops and forests, damage building materials, and impair visibility. Public awareness and concern about the problems associated with reduced air quality have increased in recent years. Nevertheless, there still remains considerable uncertainty about both the severity and the valuation of these impacts. The valuation of environmental damages can play an important role in establishing environmental policy and regulatory standards, and can provide guidance in targeting mitigation efforts. In order to achieve environmental objectives at least cost, policy-makers and managers need to balance the relevant social costs and benefits.

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 a forestation programmes). Therefore, the main fields of emission mitigation will be the energy and the forestry sectors. The main reasons are as follows:

- The overall energy efficiency is far lower than that of the industrialised market economies. The efficiency on both the demands and the supply side has to be increased even in the short run. As far as the supply side is concerned, restructuring of the power plant system is unavoidable, since many plants are old.
- Traditionally, the forestry sector is highly developed and there is enough land even for a larger a forestation programme.

Energy efficiency brings health, productivity, safety, comfort and savings to the homeowner, as well as local and global environmental benefits. The use of renewable energy resources could play an important role in this context, especially with regard to responsible and sustainable development. Implementation of renewable energy technologies offers a chance for economic improvement by creating a market for producing companies, maintenance and repair services.

REFERENCES

[1] Commission of the European Communities. [2000] Towards a European strategy for the security of energy supply, Green Paper, COM (2000) 769, Brussels, 29 November 2000.

[2] Gheorghe A, Nicolet-Monnier M. [1995] Integrated regional risk assessment, Vols I and II, Kluwer academic, Dordrecht.

[3] IAEA. [1997] DECADES Project on comparative assessment of various energy systems, Vienna.

[4] UNIDO. [2005] Changing courses sustainable industrial development, as a response to Agenda 21, Vienna.

[5] IPCC. [2008] Climate change 2008: impacts, adaptations and mitigation of climate change, Watson, R.T. et al., (Editors). Cambridge University Press, London.

[6] Rodhe H. [1990] A comparison of the contributions of various gases to the greenhouse effect, *Science* 248, pp. 1217–1219.

[7] Post WH, Peng TH, Emanuel WR, King AW, Dale VH, DeAngelis DL. [1990] The global carbon cycle, American Scientist 78, pp. 310–326.

[8] Loro L. [1993] Green marketing comes to computers, Advertising Age, September 29. 1993.

[9] U.S. Environmental Protection Agency. [1994] Determinants of effectiveness for environmental certification and labelling programmes, pp.4–18.

[10] U.S.A Environmental Protection Agency. [1993] Status report on the use of environmental labels worldwide, pp. 6-35.

[11] Omer, AM. [2008] Green energies and environment, *Renew Sust Energ Rev* 12, pp. 1789–1821.

[12] Omer, AM. [2007] Renewable energy resources for electricity generation in Sudan, *Renew. Sust Energ Rev* 11, pp. 1481–1497.

[13] Omer, AM, et al. [2003] Biogas energy technology in Sudan, *Renew Energ* 28 (3): 499–507.

[14] Omer, AM. [2005] Biomass energy potential and future prospect in Sudan, *Renew. Sust Energ Rev.*, 9: 1–27.

[15] Omer, AM. [2007] Review: Organic waste treatment for power production and energy supply, *Cells Anim Biol* 1 (2): 34–47.

[16] Omer, AM. [2009] Drinking water from solar stills: a renewable technology for Sudan, *NOVA Science Publisher Inc.*, New York: USA.

[17] Anne, G, Michael, S. [2005] Building and land management, 5th edition. Oxford: UK.

[18] David, E. [2003] Sustainable energy: choices, problems and opportunities, *The Royal Soc Chem* 19: 19–47.
[19] DEFRA. [2002] Energy Resources, Sustainable Development and Environment, Doncaster, UK.
[20] Department of Energy (DoE). [2009] Annual energy demand, USA.
[21] Zuatori, A. [2005] An overview on the national strategy for improving the efficiency of energy use. *Jordanian Energ Abs* 9 (1): 31–32.
[22] Omer, A.M. [2005] Biomass energy potential and future prospect in Sudan, *Renewe Sust Energ Rev* 9: 1–27.
[23] Omer, A.M. [2007] Renewable energy resources for electricity generation in Sudan. *Renew Sust Energ Rev* 11: 1481–1497.
[24] Abdeen M. Omer. [2009] Chapter 5: Alternative energy for future, In: Energy Costs, International Developments and New Directions, Editors: Leszek Kowalczyk and Jakub Piotrowski, *2009 NOVA Science Publishers, Inc.*, p.127–153, New York, USA.
[25] Abdeen M. Omer. [2010] Chapter 3: Utilisation and development of solar and wind resources, In: Dust Storms: Elemental Composition, Causes and Environmental Impacts, Editors: Sinisa Brstilo and Quentin Madunic, *2010 NOVA Science Publishers, Inc.*, p.111–147, New York, USA.
[26] Abdeen M. Omer, Siddig A. Omer, Saffa B. Riffat. [2010] Design and installation of direct expansion ground source heat pumps, SET 2010. August 2010.
[27] Omer, AM. [2010] Chapter 9: Development of sustainable energy research and applications, In: Handbook of Sustainable Energy, Editors: WH. Lee and VG. Cho, *2010 NOVA Science Publishers, Inc.*, p.385–418, New York, USA.
[28] Omer, A.M. [2010] Chapter 3: Environmental and socio-economic aspects of possible development in renewable energy use, In: Handbook of Environmental Policy, Editors: Johannes Meijer and Arjan der Berg, 2009 NOVA Science Publishers, Inc., p.79–114, New York, USA, 2010.
[29] Omer, AM. [2010] Sustainable energy: challenges of implementing new technologies, *Global J Technol Optim*, Vol.1, p.164–170, Malaysia, June 2010.
[30] Omer, AM. [2010] Sustainable energy development and environment, Research Journal of Environmental and Earth Sciences, Vol.2, No.2, p.55–75, *Maxwell Scientific Organisation*, USA, April 20,[2010].
[31] Omer, AM. [2008] Green energies and the environment. *Renew Sust Energ Rev* 12: 1789–1821.
[32] Omer, A.M. 2008b. On the wind energy resources of Sudan, Renewable and Sustainable Energy Reviews, Vol.12, No.8, p.2117–2139, United Kingdom, October 2008.
[33] Omer, AM. [2008] Energy demands for heating and cooling equipment systems and technology advancements. In: *Natural Resources: Economics, Management and Policy*, p.131–165.
[34] Omer, AM. [2009] Energy use and environmental impacts: a general review, *Renew Sust Energ*, Vol. (1): 1–29.
[35] World Energy Council (WEC). [2009] The world energy demand in 2020.

Appendix (1) Energy structure in Sudan

Appendix 1.1 Electricity output of present power plants in Sudan (GWh) [28]

Plants	Power (GWh)
Hydro power stations	1095.12
Steam power stations	1037.93
Diesel power stations	359.9
Gas turbine power stations	235.35
Combined power stations	1020.62
Total	3748.9
Peak load for national grid (MW)	534
Total number of consumers (head)	10700000
Total number of employees (head)	7097

Appendix 1.2 Sources of biomass energy available in Sudan 10^6 tons of equivalents (TOE) [29]

Item	Source	10^6 TOE
1.	Natural, and cultivated forests	2.90
2.	Agricultural residues	6.20
3.	Animal wastes	1.05
4.	Water hyacinth	3.16
Total		13.31

Appendix 1.3 Biomass energy consumption in Sudan 10^3 tons of equivalents (TOE) [30]

Item	Sector	10^3 TOE	(%)
1.	Residential	4549	92.0
2.	Industrial	169	3.4
3.	Others*	209	4.6
Total		4927	100.0

*Others are commercial, constructions, and Quranic schools.

Appendix 1.4 Biomass energy potential from animal dung in different states of Sudan [31]

Item	States	Animal dung available (10^3 Tons)	Energy (TOE)
1.	Northern states	102.4	1543
2.	Eastern states	1222.9	18431
3.	Khartoum state	104.3	1572
4.	Central states	4223.7	63658
5.	Darfur states	5062.5	36301
6.	Kordofan states	2596.9	79140
7.	Southern states	4545.2	68505
Total		17857.9	269150

Appendix 1.5 Annual total different biomass supply in regions of Sudan (10^3 kg) [32]

ISSN: 0976-3104

Regions	Agricultural residues	Animal waste	Bagasse
Northern	288	8548	8644
Eastern	11530	84316	84414
Central	21550	107342	131744
Khartoum	0	5766	5170
Kordofan	2733	234086	236819
Darfur	6901	173376	174067
Southern	1464	290599	197875
Total	44466	904033	838733

Appendix 1.6Annual electricity consumption in Sudan [33]

Sector	Energy	Percent of total (%)
Transportation	3.2	4%
Agricultural	22.4	28%
Industries	6.4	8%
Residential	48.0	60%
Total	80.0	100%

Appendix 1.7 Annual petroleum product consumption in Sudan (10^6 MWh) [34]

Sector	Energy	Percent of total (%)
Transportation	601	60.0%
Industries	138	13.8%
Agricultural	148	14.8%
Residential	55	5.5%
Others*	60	5.9%
Total	1002	100.0%

*Others are commercial and services.

Appendix 1.8 Annual sugarcane bagasse available in Sudan (10^3 tonnes) [34]

Factory	Design capacity	Yearly bagasse
Kenana	300	266
El Genaid	60	53
New Halfa	75	65
Sennar	100	58
Asalaia	100	60
Total	635	502

Appendix 1.9 Per capita consumption for household (10^3 kg) [34]

Fuel	Wood		Charcoal	
Region	Urban	Rural	Urban	Rural
Northern	0.28	0.38	0.83	1.08
Eastern	0.35	0.40	2.21	2.04
Central	0.30	0.58	2.25	2.05
Kordofan	0.41	1.23	5.29	2.30
Darfur	0.41	1.23	5.29	2.30
Khartoum	0.48	0.26	0.93	0.94
Equatorial	0.48	1.40	0.88	0.27
Bahar El	0.88	1.36	1.00	0.27
Ghazal	0.58	0.66	0.76	0.18
Upper Nile				

Appendix (2) Facts about Sudan [35]

Full country name	Republic of the Sudan.
Total area	One million square miles (2.5 x 10^6 square kilometres). Land 2.376 x 10^6 square kilometres.
Population	35 x 10^6 inhabitants (July 1999 est.).
Capital city	Khartoum (population 5 million).
Language	Arabic (official), English, Nubian, Ta Bedawie, diverse dialects of Nilotic, Nilo – Hamitic, Sudanic languages.
Religions	Sunni Muslim 70% (in north), indigenous beliefs 25%, Christian 5% (mostly in south and Khartoum).
GDP per head	US $ 533.
Annual growth	4% (1997 est.).
Inflation	23% (1998 est.).
Ethnic groups	Black 52%, Arab 39%, Beja 6%, Foreigners 2%, others 1%.
Agricultures	Agriculture is the backbone of economic and social development. 62% of the populations are employed in agriculture. Agriculture contributes 33% of the gross national products (GNP), and 95% of all earnings.
Animal wealthy	35 x 10^6 head of cattle. 35 x 10^6 head of sheep. 35 x 10^6 head of goats. 3 x 10^6 head of camels. 0.6 x 10^6 head of horses and donkeys. Fish wealth 0.2 x 10^6 tonnes of food annually. Wildlife, birds and reptiles.
Environment	Inadequate supplies of potable water, wildlife populations threatened by excessive hunting, soil erosion, and desertification.
International agreements	Party to: Biodiversity, climate change, desertification, endangered species, law of the sea, nuclear test ban, ozone layer protection.

ACKNOWLEDGEMENT

A special thanks to my spouse Kawthar Abdelhai Ali for her support and her unwavering faith in me. Her intelligence, humour, spontaneity, curiosity and wisdom added to this article.

ABOUT AUTHORS

Dr. Abdeen Mustafa Omer *(BSc, MSc, PhD) is a qualified Mechanical Engineer with a proven track record within the water industry and renewable energy technology. He has been graduated from University of El Menoufia, Egypt, BSc in Mechanical Engineering. His previous experience involved being a member of the research team at the National Council for Research/Energy Research Institute in Sudan and working director of research and development for National Water Equipment Manufacturing Co. Ltd., Sudan. He has been listed in the WHO'S WHO in the World 2005, 2006 2007 and 2009. He has published over 200 papers in peer-reviewed journals, 50 review articles and 40 chapters in books.*