Transaction in Energy, biotechnology, planning and Environment
ISSN: 1985-9406 Online Publication, June 2010
www.pcoglobal.com/gjto.htm
SE-E13/GJTO

Global Journal on Technology & Optimization
Volume 1, 2010

SUSTAINABLE ENERGY: CHALLENGES OF IMPLEMENTING NEW TECHNOLOGIES

Abdeen Mustafa Omer

Juniper Court, Nottingham, UK
Email: abdeenomer2@yahoo.co.uk

Received May 2009, Revised June 2009, Accepted January 2010

Abstract
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 (biomass, petroleum products, and electricity); and non-conventional energy (solar, wind, hydro, etc.). Sudan possesses a relatively high abundance of sunshine, solar radiation and moderate wind speeds, hydro and biomass energy resources. 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. 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. Sustainable low-carbon energy scenarios for the new century emphasise the untapped potential of renewable resources. 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, consumption patterns, renewable energy potential, sustainable development, impacts on environment, mitigations.

1. Introduction

Sudan is the largest country in African continent, with a tropical climate, and an area of approximately 10^6 square miles (2.5 x 10^6 km^2). It lies between latitudes 3°'N and 23°'N; and longitudes 21° 45' 'E and 39°'E. This large area enjoys a variety of climates, from desert regions in the north, to tropical in the south, and makes it a favourable environment for all activities of integrated agricultural investment from production to processing industries [1]. Sudan is a relatively sparsely populated country. The total population according to the census 1996 was 30 x 10^6 inhabitants. The annual growth rate is 2.8%, and population density is 12 persons per square kilometre [1]. Sudan is rich in land and water resources [2]. Sudan has a predominately-continental climate, which roughly divides, into three climatological regions:

Region 1 is situated north of latitude 19°'N. The summers are invariably hot (mean max. 41°C and mean min. 25°C) with large variation; low relative humidity averages (25%). Winters can be quite cool. Sunshine is very prevalent. Dust storms occur in summer. The climate is a typical desert climate where rain is infrequent and annual rainfall of 75-300 mm. The annual variation in temperature is large (max. and min. pattern corresponding to winter and summer). The fluctuations are due to the dry and rainy seasons.

Region 2 is situated south of latitude 19°'N. The climate is a typical tropical continental climate.

Region 3 comprises the areas along the Red Sea coast and eastern slopes of the Red Sea hills. The climate is basically as in region 1, but is affected by the maritime influence of the Red Sea.

Two main air movements determine the general nature of the climate. Firstly, a very dry air movement from the north that prevails throughout the year, but lacks uniformity; and secondly, a major flow of maritime origin that enters Sudan from the south carrying moisture and bringing rain. The extent of penetration into the country by airflow from the south determines the annual rainfall and its monthly distribution. The average monthly rainfall for Sudan indicates the decreasing trend in the rainfall, as well as in the duration as one moves generally from the south towards the north and from east towards west. The total size of the land of Sudan is 6 x 10^8 Feddans (Feddan = 1.038 acres = 0.42 hectares). The land use in the country is classified into four main categories. There are arable land (8.4 x 10^6 hectares), pasture (29.94 x 10^6 hectares), forest (108.3 x 10^6 hectares), and about 38.22 x 10^6 hectares used for other purposes. Water resources are estimated at 84 x 10^9 cubic meters (m^3), this including the river Nile and its tributaries. Underground water is estimated

at 26 x 10^{10} cubic meters, only 1% of this amount is currently being utilised. The annual average rainfall ranges from about 1 mm in the northern desert to about 1600 mm in the equatorial region. The total annual rainfall estimated at 1093.2 x 10^9 m^3.

Sudan's economy remains essentially agricultural, with annual agricultural production, estimated as 15 x 10^6 tonnes mainly sugar, wheat, sorghum, cotton, millet, groundnut, sesame, tobacco, and fruits [2]. Sudan is also viewed as one of the potentially richest nations in livestock [2], approximately 103 x 10^6 head (70 x 10^6 sheep and goats, 30 x 10^6 cattle, and 3 x 10^6 camels) [3]. Sudan has a great wealth of the wild life- birds, reptiles, and fishes. Sudan possesses great potentialities for industrialisation since it is rich in agricultural raw materials resources. Since the government realised the importance of industrialisation for economic development, there were many attempts by the state to improve the performance of this sector through different industrial policies. Energy is an essential factor in the development movement, since it stimulates and supports the economic growth, and development. The energy crisis in mid seventies, and substantial increase in oil prices that followed, has put a heavy financial burden on the less developed countries (LDC's). Sudan is not exception. The fossil fuels, especially oil and natural gas, are finite in extent, and should be regarded as depleting assets, and since that time, the efforts are oriented to search for new sources of energy. Most of the political and resources are directed to establish sources of energy, many of which now face serious environmental and other constraints, rather than the biomass sources which are increasingly being regarded as a central parts of long solutions to the energy environment dilemma. However, increasing energy service levels with the same environmental goals would imply stronger exploitation of biomass energy sources and stronger measures for exploiting the potential of energy conservation. In recent years, Sudan has increased efforts to exploit renewable energy sources and reduce its dependence on oil. Wind, solar and biomass offers a variety of renewable options that are well suited to the African climate. A number of renewable energy initiatives are under way in Sudan that can contribute to rural development while also addressing climate mitigation.

2. Energy situation

Sudan like most of the oil importing countries suffered a lot from sharp increase of oil prices in the last decades. The oil bill consumes more than 50% of the income earnings. Sudan meets approximately 87% of its energy needs with biomass, while oil supplies 12%, and the remaining 1% is produced from hydro and thermal power. The household sector consumed 60% of the total electricity supplies [4]. The total annual energy consumed is approximately 11 x 10^9 tonnes of oil, with an estimated 43% lost in the conversion process [5]. The heavy dependence on biomass threatens the health and future of domestic forests, and the large quantities of oil purchased abroad causes Sudan to suffer from serious trade imbalances. Poverty and iniquity in the basic services are the major components that hindered rural development. Unless being addressed now, non-of the great goals of the international and nation community peace, human rights, environment, and sustainable development will be achieved or even progressed. Energy is a vital prime mover to the development whether in urban or rural areas. The rural energy needs are modest compared to urban. A shift to renewables would therefore help to solve some of these problems while also providing the population with higher quality energy, which will in turn, improve living standards and help reduce poverty. For proper rural development, the following must be considered:

- Analyse the key potentials and constraints development of rural energy.
- Assess the socio-technical information needs for decision-makers and planners in rural development.
- Utilise number of techniques and models supporting planning rural energy.
- Design, import and interpret different types of surveys to collect relevant information and analyse them to be an input to planners.

Renewable energy technologies such as solar, wind, etc. become more important since there are local resources, and infinite source of energy. Renewable energy needs, especially in rural areas and small communities. Renewable sources of energy are regional and site specific. The renewable strategy is well integrated in the National Energy Plan [6], and clearly spelled out in the National Energy Policy, but this is not enough. It has to be integrated in the regional development plans. The role of renewable is big in solving essential life problems especially in rural areas for people and their resource development like the availing of energy for the medical services for people and animal, provision of water, education, communication and rural small industries [7]. A new renewable fuels program in Sudan aims to improve environmental standards while making better use of domestic resources, providing an economic stimulus to the rural economy, and reducing CO_2 emissions. This article discusses Sudan's current energy system, and describes plans for expanding and improving Sudan's emerging portfolio of renewable energy options. The poor situations of conventional energy supplies to Sudanese people are characterised by high dependence on biomass woody fuels (firewood, and charcoal). More than 70% of the total Sudanese population live in rural and isolated communities characterised by extreme poverty and power social, and economical activity [8]. The unavailability and the acute shortages of the conventional energy supply (petroleum and electricity) to rural people forced them to use alternatives available energy sources like biomass [9]. This situation caused serious environmental degradation beside the poor unsatisfactory services of some basic needs such as:

- Food security
- Water supply
- Health care
- Communications

Due to the present limitations, and sharp shortages or unavailability of both electricity and petroleum products to rural people, some renewable energy technologies based on utilising locally available energy; materials and skills are alternate energy options to rural development [10]. These technologies are not for complete rural electrification (although they can), but they are applied as energies stand-alone systems providing energy sources to some rural basic needs. It is necessary that a vigorous program for renewable energies should be set up immediately (the challenge is to provide a framework enabling markets to evolve along a path

that favours environmentally sustainable products and transactions).

3. Renewable energy resources

The present position for most people in Sudan for obtaining the needed energy forms (heat, light, etc.) is provided by firewood. Cooking is largely done by wood from forests or its derivative, charcoal. Cattle dung and agriculture waste being used to lesser extent. Human, animal, and diesel or gasoline engines provide mechanical power. Some cooking and lighting is done by kerosene. It should be recognised that this situation is unlikely to be charged for the next one or two decades. However, because of the need to increase energy availability and also to find alternatives to the rapidly decreasing wood supplies in many rural areas. It is necessary that a vigorous program reaching into alternative renewable energies should set up immediately. There should be much more realism in formation of such program, e.g., it is no use providing a solar powered pump at a price competitive with a diesel for some one who can not ever offered a diesel engine. The renewable energy technology systems (RETs) are simple, from local materials, clean energy, reliable and sustainable. Specialist on their applications carried out socio-economic and environmental studies. The output of the studies pointed out that, they are acceptable to the people and have measured remarkable impacts on the social life, economical activities and rural environment [11, and 12].

4. Achievements

In 1991, Sudan created the Ministry of Higher Education and Scientific Research (MHESR) to take responsibility for all matters relating to non-conventional/renewable energy. It undertakes the role of renewable energy policymaking, planning, promotion, and coordination. In recent years Energy Research Institute (ERI)-National Centre for Research (NCR)-MHESR has overseen the development of a broad base of technologies including biogas plants, solar thermal and PV systems, wind turbines, small and micro hydropower units, energy from urban and industrial wastes, and even improved cooking stoves. Under the present federal system, Sudan is divided into 26 federal states. This made regional development planning a more important tool for the utilisation of natural resources particularly planning for the utilisation of renewable energy sources. The role of renewable energy is big in solving essential live problems especially in rural areas for people and their resource development like the availing of energy for the medical services for people and animal, provision of water, education, communication and rural small industries. Consequently, the energy plan includes:

- Installation of 200 solar pumps in the rural areas every year to achieve self-satisfaction of drinking water in areas suitable for solar applications.
- Utilisation of solar energy in the telecommunications to cover by the end of the plan all existing airports, and the railway stations, the remote hospitals and microwave stations through the installation of 300 units.
- Lighting of rural areas at a level of 2 MW every year starting with 50 kW (8 MW for 10 years of the program).
- Popularise the use of solar refrigerators by the installation of 300 units per year for vaccines and medicines preservation for human beings and animals.
- Supply distilled water by producing 1000 m^3 of distilled water every year.
- Solar water heating in hotels, hospitals, and relevant industries through the installation of 500 units every year.
- Disseminate the use of solar cookers in the northern states for household use through the production of 1000 units every year.
- Production of 60 wind pumps for Sudan rural areas.
- Production of 200 current driven pumps per year.
- Installation of 50 biogas units per year.
- Support research and development for:
    1. Biomass gasifiers (stand-alone)
    2. Biomass combustion/gasifier
    3. Bagasse based cogeneration
    4. Ethanol production from sugar cane
    5. Floating pumps
    6. Wind generators
    7. Solar collectors
    8. Solar dryers

5. Environmental policies and industrial competitive

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 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:

(1) Implementing ecologically sustainable industrial development strategies:

Agenda 21 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'' [13]. 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 subsectors 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.

(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 subsectoral 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.

(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 programs by industry association and bilateral and multilateral agencies.

(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.

(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.

(6) Counteracting threats from eco-labeling 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 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.

(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 programs 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.

(8) Addressing concerns of small and medium scale industry (SMI):

Small and medium scale enterprises not only contribute to productivity growth and employment but also 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.

6. Petroleum industry pollution and greenhouse gases emissions

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 x 10^9 cubic meters. 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. In the year 1997, about 2 x 10^9 tonnes of petroleum products were burnt in Sudan. This amount will be doubled in the year 2010. There is a shortage of information concerning the area of greenhouse gases recording in Sudan.

7. 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 renewable.

(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 specialized 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 organizations 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.

8. Mitigation measures

Mitigation measures that could be under taken to influence the effect of oil industry and use that may contribute in decreasing (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.
- 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). Activating, supporting environmental, and pollution control activities within the Ministry of Energy and Mining (MEM) to effectively cope with the evolving oil industry in Sudan.
- The development of effective environment standards, policies, laws and regulations particularly in the field of oil industry.

9. 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.

Industry's use of fossil fuels has been blamed for our warming climate, when coal, gas and oil are burned, they released harmful gases, which trap heat into atmosphere and cause global warming. However, there has been 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.

10. Recommendations

Recommendations may be classified into three broad categories: policy, institutional and enterprise levels.

(1) Policy level action:

At the policy level, the following aspects may be considered:

- Giving priority to pollution prevention rather than pollution control.
- Using market based instrument complements to command and control measures.
- Recognising small and medium scale industry (SMI) as a special case in environmental legislation.
- Adopting proper industrial sitting and relocation policies.

(2) Institutional level actions:

- Setting up environmental extension services for small and medium scale industry (SMI).
- Creating information dissemination cells.
- Facilitating common waste treatment facilities.
- Promoting outreach from large plants to small and medium scale industry (SMI).

(3) Enterprise level actions:

- Supporting demonstrations of the financial environmental benefits of pollution prevention measures.
- Promoting self-initiated demonstrations at enterprises through the provision of grants to enterprises.

11. 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 recognized the potential to alleviate some of these problems by promoting renewable energy and utilizing 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.

Sudan's energy system is in the midst of a transition away from fossil fuels towards a more sustainable energy system based on biomass and other renewable options. Biogas plants offer renewable options that are relatively inexpensive and well suited to rural areas. Hydropower will continue to play a role in smaller-scale energy supply. There is also potential for expanding wind and solar applications in Sudan, particularly in rural areas.

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. It represents an excellent opportunity to offer a higher standard of living to the local people, and will save local and regional resources. Implementation of renewable energy technologies offers a chance for economic improvement by creating a market for producing companies, maintenance and repair services.

References

[1] Omer, A.M. Rainfall patterns in Sudan. NETWAS News 2 (7): 4-7. 1995.

[2] Omer, A.M. Sudan energy background; an overview. Renewable Energy 14 (1-4): 467-472. 1998.

[3] Omer, A.M. Sudan Experience in Biomass Energy. Khartoum: Sudan. 1999.

[4] Energy Research Institute (ERI). Renewable Energy Resources Potential in Sudan, Khartoum: Sudan. 1987.

[5] Omer, A.M. Review of Hydropower in Sudan. Khartoum: Sudan. 1997.

[6] National Energy Administration (NEA). The National Energy Plan 1985-2000. Khartoum: Sudan. 1985.

[7] Omer, A.M. Renewable energy technology applications in the Sudan. In Proceedings of the 3rd World Renewable Energy Congress, Reading, UK, 11-16 September. Oxford: Elsevier Science Ltd. 1994.

[8] Omer, A.M. Renewable energy potential and future prospect in Sudan. Agriculture and Development in Arab World 3 (1): 4-13. 1996.

[9] Omer, A.M. Biogas technology and environment. Regional Energy News 2(4): 2-5. 1996.

[10] Omer, A. M. Solar energy technology applications in the Sudan. In Proceedings of the 1st Jordanian, Mechanical Engineering Conference, Amman, Jordan 25-28 June Amman: Jordanian Mechanical Engineering Association. 1995.

[11] National Energy Administration (NEA). Renewable Energy Assessment for the Sudan. Khartoum: Sudan. 1983.

[12] National Energy Administration (NEA). A Pre-investment Study for Fuel Production from Agricultural Wastes for Power Generation and Household Consumption, Khartoum: Sudan. 1983.

[13] Omer, A.M. Renewable Energy Potential and Environmentally Appropriate Technologies in Sudan. Khartoum: Sudan. 1998.