Sustainable Energy Potential in Sudan

Tarig Mubark Saeed, Eisa Bashier M. Tayeb, Giddani Osman

School of Electrical and Nuclear Engineering, Sudan University of Science &Technology
Tarig.mubark88@yahoo.com

Received:15/06/2019
Accepted:18/10/2019

ABSTRACT- Sudan is in the midst of energy transition after it lost its oil-rich south in a referendum in 2011. The country also intends to contribute in combating climate change affects. It is a challenging task for a country like Sudan since its primitive non-environmentally friendly energy practices have and continue to be the country's largest energy source. The country realized the importance of renewable energies in helping with this transition and set goals. There are many types of Renewable which provide clean environmental-friendly energies. These range from biomass (bioenergy), hydropower, solar, wind energies and more others. With a country like The Sudan that has vast areas of fertile land, abundance of minerals, water, winds and sunshine, many types of these energies become a valid option. This paper reviews all the comprehensive compilation of data related to potential, current status and the challenges on critical parameters for all the important sectors of the Sudanese renewable energy industry.

Keywords: *Renewable Energy, National Grid, Sustainable Energy in Sudan, photovoltaic (PV), Wind energy,*

المستخلص *– يمر السودان بمرحلة تحول في مجال الطاقة وذلك بعد أن فقد جنوبه الغني بالنفط في استفتاء عام2011 ، وتعتزم الدولة المساهمة في مكافحة آثار تغير المناخ على الرغم من إنها مهمة صعبة بالنسبة لبلد مثل السودان حيث أن ممارسات الطاقة البدائية غير الصديقة للبيئة تعتبر ولا تزال أكبر مصدر للطاقة في البلاد. أدركت الدولة أهمية الطاقات المتجددة في المساعدة في هذا الانتقال وتحديدالأهداف.هناك العديد من أنواع الطاقات المتجددة التي توفر طاقات صديقة للبيئة ونظيفة. وتتراوح هذه بين الكتلة الحيوية (الطاقة الحيوية) ، والطاقة المائية ، والطاقة الشمسية ، وطاقة الرياح وغيرها . كبلد مثل السودان يحتوي على مساحات شاسعة من الأراضي الخصبة و وفرة من المعادن والمياه والرياح وأشعة الشمس، ولذلكأصبحت أنواع كثيرة من هذه الطاقات خيارًا صالحًا للإستخدام . تستعرض هذه الورقة جميع البيانات المتعلقة بالوضع الحالي و المحتمل و التحديات المتعلقة بالمعايير المهمة لجميع قطاعات صناعة الطاقة المتجددة في السودان.*

INTRODUCTION

Nowadays, the major and primary source of electrical energy is fossil. Fossil fuels cover about 79% of the primary energy consumed in the world, including heating, transportation and electrical generation. It's convenient to use coal, oil, and natural gas for meeting the energy needs, but there is a limited reservoir of these fuels on the Earth. It is very important to find alternative instead of fossil fuel in case they will are totally exhausted.

Renewable energy, clean and friendly environmental alternative will dominate the energy sector in the near future. Renewable energy reduces the emission of CO2 in atmosphere. The renewable energy sources like wind energy, solar energy, geothermal energy, ocean energy, biomass energy and fuel cell can be used to improve the energy sector in Sudan and overcome the dramatically energy shortage in next decades [1].

The governmental plans to supplies the electrical power to remote areas and extension of the national grid to cover the whole country required sustainable and continuous power generation to supply the electrical demand. The current status of electrical energy in Sudan is not satisfactory, the power supply position prevailing in the country is characterized by persistent shortages, unreliability and high prices for industrial consumers. The power generation depend on imported oil, and this naturally raises issues about energy security.

It is very important to investigate the renewable energy potential to provide suitable solutions in long term for energy problems in Sudan. The utilization of renewable energy required resources,

tools, technologies and scenarios for implementation of proposed projects [2, 3]. The general objectives are:

- Utilizing Sudan Renewable Energy Potential.
- Setting an example for the economic feasibility of Sudan Renewable Energy resources.
- Raising the Standard of Living in Sudan.
- Lowering of Sudan Carbon Emissions and contributing to the Environment.

Motivations

The main purpose of this Study is to present a realistic approach for assessing the feasibility of Renewable Energy development in Sudan in General. This paper is initially aimed at serving as a meticulous guide for Renewable Energy developers in Sudan via highlighting the local risk assessment.

The main driver of this paper is to create a system in which both Stake holders can benefit from the positive externalities which result from the implementation of a sustainable energy project. It is expected that this system creates jobs for the community and provides the citizens with reliable, clean and easily accessible electricity. At the same time, the Projects should self-sufficiently create revenues to pay for investment and Loans.

Network (National Grid) Current Situation

Sudan's Electrical power sector has been subject to poor infrastructure and experiences frequent power outages. At present the country's electricity generating capacity consists of about 1700 Megawatts of thermal power and about 1600 megawatts of hydropower capacity, and total electricity generation is around 15 billion kilowatt hours (Bow).

Electrical generation stations which operate by fuel produce around 50% of the total electrical supply of the country. Hydro power makes up the reminder. The upper Atbara and Setit dam are expected to increase Hydro Production.

Last December 2016, the United Nations Development Programme (UNDP) said that Sudan will face a problem in electricity production in the future if it does not develop alternative projects due to decreased rainfall and increased consumption. According to the UN, 35% of Sudan's population has access to electricity while more than 25 million people are not yet been connected to the national electricity grid. International figures put electricity access figures as follows:

- Population without electricity: 24,700,000
- Electrification - total population: 35%
- Electrification - urban areas: 63%
- Electrification - rural areas: 21%

Sudan's primary energy supply is estimated as 14.8 million tons of oil equivalent (toe) of which biomass resources accounting for 62%, fossil fuels 34% and electricity 4% of total energy supply. However, Sudan achieved improvements in the energy supply situation during the last 10 years due to the use of indigenous oil reserves and dams construction along the Nile, the South Sudan cession present a huge setbacks in the energy supply situation in Sudan. Following the secession of South Sudan in July 2011, Sudan has lost 60% of its biomass energy resources, 75% of its oil reserves and 25% of its hydropower potential. This new development poses critical energy supply situation of all primary sources due to dwindling stock of energy resources from one side and increased population from the other side.

According to the Energy Situation Analysis Report, about 70% of the population currently has no access to electricity and about 92% of the population use biomass for cooking purposes. As an LDC (ranked 166 out of 187 countries on the Human Development Index, 2014) and with 46.5% of its population officially living in poverty (and many more near the poverty line), Sudan population are extremely vulnerable to energy supply constraints.

In particular the population living in rural and remote areas will receive much of the negative impacts of insufficient energy supply situation. Besides, even this low use of modern energy it shows also wide disparities in distribution and use of modern services between the different States.Figure 1 shows the current status of the national grid and the primary source coverage penetration [3,4].

Sustainable Energy in Sudan

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 total energy consumed is approximately 11.7 million tons of oil equivalents (TOE), with an estimated 30 % lost in the conversion process. 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. A shift to renewable 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.

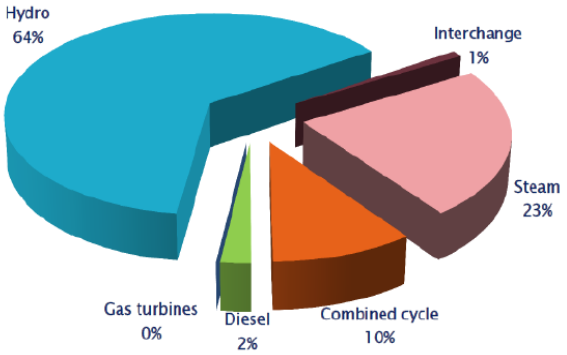

Figure 1: Current Power Generation Status

Three renewable resource options that fit well with Sudan's unique resource needs and endowments are wind, solar stills, and biogas. Wind pumps and solar stills have been pursued on a wide scale in Sudan and are discussed below. The potential for biogas options is well known, but it has not yet been widely pursued [5].

Solar

Solar energy possesses characteristics, which make it highly attractive as a primary energy source. It is based upon a continuously renewable resource which cannot be depleted and which is not subject to political control.

The location of Sudan as part of Sahara and tropical area enrich the solar potential. The average temperature ranges from 28 to 39°C. Average solar insolation in the country is roughly 6.1 kWh/m2/day, indicating a high potential for solar energy use. Total potentials over the course of a year have been estimated at 10.1 GJ/m2.

A recent Global Environmental Facility (GEF), UNDP-funded project, utilized PV to electrify 13 rural and peri-urban communities, with some 45,000 households in the country now using PV systems. The Northern State has been considered as one of the best parts of the Sudan for exploiting solar energy as shown in Figure 2. The climate in Northern state is typical desert where rain is infrequent and annual (the sun is rarely obscured by cloud; the main reflection factor of solar radiation).

The cities with highest solar radiation are in the northern and western parts of the country, namely Dongola, 6.7 kWh per meter squared per day, and El Fasher, 6.4 kWh per meter squared per day.

Solar energy applications can be divided into two main categories: solar thermal application and photovoltaic technologies (PV). Solar thermal is a technology where the heat from solar energy is harnessed for heating purposes, while photovoltaic is a technology where arrays of cells which contain solar photovoltaic material convert the solar radiation into direct current electricity.

Figure 3 illustrate the solar potential for the suitable location for utilization of solar power in Sudan based on the duration of sun shining per hour and solar radiation (kwh/m2/day)[6,7].

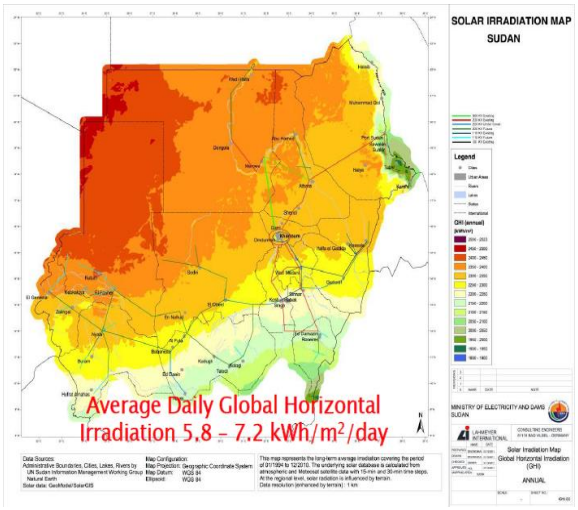

Figure 2:Global Horizontal Irradiation (GHI) in Sudan[3]

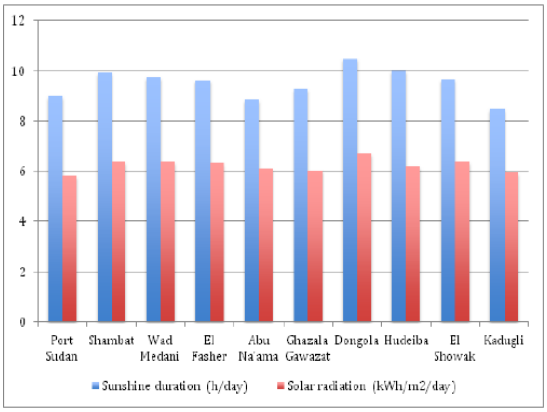

Figure 3: Solar Potential of Different Cities in Sudan

Wind

Wind energy has considerable resources in Sudan where the annual average wind speeds

exceeds 5 ms^{-1} in the most parts north latitude 12° 'N, and along the Nile valley. While the southern regions have the poorest potential because of the prevailing low wind speeds.

The extractable energy is ranging from 400-600 kWm^{-2} $year^{-1}$. Experience in wind energy in Sudan was started since 1950s, where 250 wind pumps from Australian government, had been installed in El Gezira Agricultural Scheme for water pumping. But due to difficulties of obtaining spare-parts and availability of diesel pumps, these machines were not working now.

In the last 15 years Energy Research Institute (ERI) installed 15 CWD 5000 wind pumps around Khartoum area, northern state, and eastern state. Now ERI with cooperation of Sudanese Agricultural Bank (SAB) Introduced 60 wind pumps to be use for water pumping in agricultural schemes, but not yet manufactured due to lack of financial support[4].

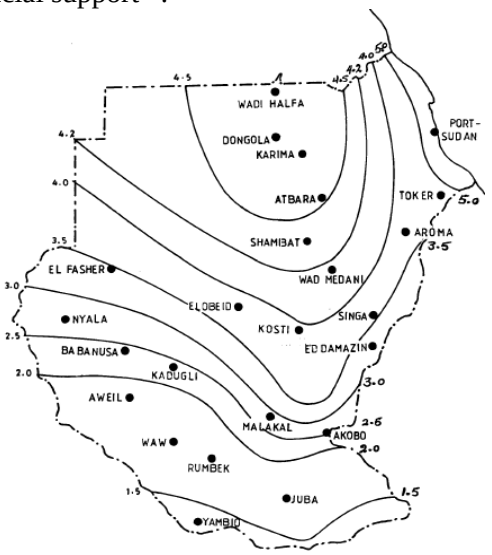

Figure 4: Annual Average wind Speed of Sudan (ms^{-1}) [5]

In areas where is wind energy potential but no connection to electric grid, the challenge is simplicity of design, and higher efficiency. Local production of wind machines should be encouraged in both public and private sectors. The research and development in the field of wind machines should be directed towards utilizing local skills and local available materials.

The presented work on development of a mechanical wind pump has going on in Sudan for several years. It is based on a multi-bladed rotor with high efficiency. The aim has been to develop a wind pump, which needs limited service; and maintenance and meets for mass production [8,9].

Average Wind speeds are estimated at 3-6 m/s; higher speeds have been recorded along the Red Sea coast. Average wind density in Sudan is estimated at 400 W/m2. Wind energy in Sudan is currently used for pumping water from both deep and shallow wells to provide drinking water and irrigation through the use of wind pumps. A Memorandum of Understanding (MOU) was signed in 2010 with the Dubai-based Omene Energy for the construction of 500 MW of wind power capacity along the Red Sea coast in Sudan, in blocks of 100 MW, to be operated under an IPP structure.[12]

Data is obtained from the Meteorological Department Office, Sudan. Measurements were with a cup anemometer coupled to a chart recorder for selected stations. Mean monthly wind speeds were tabulated for the 70 meteorological stations and mean annual wind powers were derived. Based on these data an isovent map was developed showing the distribution of wind speeds all over the country Figure 4. The isovent map reflects the potential for wind energy in Sudan.

Mean wind speeds of 4.5 ms^{-1} are available over 50% of Sudan, which well suited for water lifting and intermittent power requirements, while there is one region in the eastern part of Sudan that has a wind speed of 6 ms^{-1} which is suitable for power production.

The data presented in this paper can be considered as nucleus information for executing research and development of wind energy projects; at the same time, they could determine sites that are likely to have a better prospect.

Local manufacturer, whenever possible, is to emphasized to avail wind pump systems. Low cost designs as well as reliable devices have to be provided. According to the investigation on real demand and purchasing power of the rural people, more than 80 wind pumps will be installed before year 2020. Thus, the prospects of wind pumps are bright.

Biomass

Biomass includes solid biomass (organic, non-fossil material of biological origins), biogas (principally methane and carbon dioxide produced by anaerobic digestion of biomass and combusted to produce heat and/or power), liquid biofuels (bio-based liquid fuel from biomass transformation, mainly used in transportation applications), and municipal waste

(wastesproduced by the residential, commercial and public services sectors and incinerated in specific installations to produce heat and/or power).

There is a vibrant co-generation industry in Sudan, with installed capacity estimated at 55.5 MW in sugar factories, mainly for own use. There are plans to further expand co-generation in sugar production with more advanced plant equipment. In addition, plans are currently being developed to use an agricultural pest, the Mesquite shrub, for household energy production.

An estimated 41.4 million hectares of forest resources are present in Sudan, with an allowable cut of approximately 15.1 million cubic metres. In addition, significant potential exists for the utilisation of agricultural residues, particularly crop residues and animal waste. Also, the government plans to add significant bioethanol and biodiesel production capacity in the coming years, in the region of 60 million liters/year and 50 million liters/year respectively.

Geothermal

Geothermal potential is estimated at 400 MW of power generation capacity. Potential geothermal fields have been identified near the Jabel-Marra volcano, the Tagbo and Meidob hills, the Bayud volcanic field and the Red Sea coast. Hot spring temperatures in the Red Sea region range from 56ºC to 85 ºC.

Two sites of particular interest in the region are the Suakin-1 and Bashayer-1A wells, which both have temperature gradients of over 70ºC. The country is currently collaborating with KenGen, the Kenyan national utility, to further build capacity and assess potentials in the region.

Hydropower

Total potential for hydropower in the country is estimated at 4,860 MW, with an annual production of 24,132 GWh. Small-hydro also offers a significant potential, with more than 200 suitable sites for in-stream turbines existing. In 1962 it was a first Hydro power plant to generate electricity from Sinnar Dam with a capacity of 15 MW. Sudan has five hydro power plants with a total capacity of 1,593 MW,

i. Sinnar Power plant: consists of two units with total capacity of 15 MW (1962)
ii. Elgria Power plant: consists of three pumps Turbine and two units with a total capacity of 17.8 MW (1964)
iii. Roseires Power plant: consists of seven units with total ge capacity of 280 MW. (1971)
iv. JabelAwlia Power plant: consists of 80 units with total capacity of the plant is 30.4 MW. (2005)
v. Merowe Dam Power plant : its recent and bigger dams which erected in 2009, it is consists of (10) units with total capacity of 1250 MW. Merowe Dam power evacuated via transmission of high-voltage (500 kV) for the first time in Sudan.

Total Hydro generation now 1593 MW,Due to the electrical energy demand growth the ministry of water resources & electricity plans to increase the generation capacities with different sources as well as conventional and renewable energy. The short-term plan 2016-2020 comprise of the following projects: To use available hydro potential for the following projects. Table 1, shows current and candidate hydro plan

TABLE 1: CURRENT AND CANDIDATE HYDRO PLAN

No	Dam	Capacity (MW)
1	Up Atbara - Sitat	320
2	Kajbar	360
3	Dagash	312
Total		982

Challenges and Limitation

There are many challenges facing the utilization of renewable power in Sudan which can be summarized as follow:

Planning and location sites

One of the biggest issues in renewable power utilization is the selection of proper location for installation of selected renewable power plants. The selected location should enhance and improve the reliability and security of the national network. The trend of decentralization and distributed generation drive the power system planers to select the remote areas to install the renewable energy power plants.

The national electricity network transmission capacity in overloaded and cannot withstand any additional capacity. It is very important to place the renewable power plants closed to load centers in Khartoum, areas out of national electricity network [12].

Finance

The Ministry of Water Resources, Irrigation, and Electricity (MWRIE) is the prime body responsible for the Generation, Transmission and Distribution of electric power in Sudan. There are no independent power producers (IPPs) in the country, though initiatives are underway to promote private investment in power generation.

The financing of renewable power plants needs cooperation between government, private sector and international bodies. The government must encourage the private sector to invest in installation of renewable power. Also, Renewable energy project, financially must be supported by the Global Environment Facility (GEF) and UNDP. The fund must be used in researches in renewable energy by universities and institutes, improving renewable power technologies and installation of projects in selected areas [10,11,13].

Technology Challenge

Utilization and converting the renewable energy required effective and economical technologies. The developed technologies must possess excellent technical characteristics with reasonable cost. It very important in term of economic that the cost of generated power to compete the cost of power generated by fossil energy.

It well known that the prices of fossil fuel and conventional power technologies are low in the energy market. Rigorous methods are needed to accelerate the development and utilization of renewable energy technologies, and to increase its contribution to the current energy supply mixes.

It is essential for Sudan to establish renewable industry to manufacture wind turbines, solar PV cells, biogas probe and associated technologies will help a lot in enhancing the utilization of renewable energy [16,17].

Integration of Renewable Power into Main Grid

The variation of generated power from renewable sources is due to weather condition. The variation of injected power would influence the main grid in term of frequency, voltage and system stability. In some cases, variable renewable to complement each other at different times (e.g. solar power during the day, wind power overnight) and/or in different regions (South, North). The integration of a significant share of variable renewable into power grids requires a substantial transformation of the existing networks in order to[14,15]:

i. Allow for a bi-directional flow of energy; that is top-down (from generators to users) and bottom-up (with end-users contributing the electricity supply) aimed at ensuring grid stability when installing distributed generation
ii. Establish an efficient electricity-demand and grid management mechanisms aimed at reducing peak loads, improving grid flexibility, responsiveness and security of supply in order to deal with increased systemic variability
iii. Improve the interconnection of grids at the regional, national and international - al level, aimed at increasing grid balancing capabilities, reliability and stability;
iv. Introduce technologies and procedures to ensure proper grid operation stability and control (e.g. frequency, voltage, power balance) in the presence of a significant share of variable renewables
v. Introduce energy storage capacity to store electricity from variable renewable sources when power supply exceeds demand and aimed at increasing system flexibility and security of supply.

Modern, high-voltage, direct-current (HVDC) transmission lines for long distances are highly efficient though their implementation takes time and involves significant upfront investment. Grid interconnection also requires full integration of the grid management systems.

Renewable Power plants Scenarios in Sudan

To meet the increase in load demand for the next 10 years which is expected to be 20GW in 2030 the power generation must increase from 4GW to 20 GW. Renewable energy can provide 80% of the shortage which is 10 GW from solar, wind and biogas. According to renewable potential in Sudan the following project can be installed as follow:

1. Solar PV power plant in elbagier
2. Solar thermal palnt in Dongla
3. Hybrid solar and wind power plant in Nyla
4. Wind power

Acknowledging the huge potential for renewable energies in Sudan, The Ministry of Electricity and Dams of Sudan (MED) intends to Develop Renewable energy power projects in order to promote sustainable Development. In the initial stage, MED has foreseen to focus on wind energy

projects and awarded a contract to Lahmeyer International (LI) as consultant for the development of the first seven Projects [18]:

i. 5 MW Nyala Solar Power Project

The aim of this project is to establish reliable electric power supply to Nyala city isolated grid in western Sudan by construction of solar power project.

Technical Scope: The Project will require the design, engineering, procurement, construction, testing, commissioning, operation and maintenance of a fixed tilted ground-mounted photovoltaic power plant of approximately 5 MWp installed PV power together with associated infrastructure and facilities. Table 2 shows the metrological data- nyala solar power project

TABLE 2: METROLOGICAL DATA- NYALA SOLAR POWER PROJECT

Maximum Temperature	50 °C
Minimum Temperature	5 °C
Average Humidity	44%
Maximum wind speed	6.5 M/sec
Pollution level	Normal

Location: Nyala city is in the western region at 12°2′11″N 24°52′37″E. The PV Plant will be located to the northwest of Nyala city. The average annual solar irradiation rate is high at 2,330 kWh/m2.The terrain is suitable for PV applications. The total available area for the PV plant is approximately one square kilo-Meter.

ii. 10MW Khartoum Solar Power Project

The aim of this project is to establish reliable electric power supply to National Grid in the central part of Sudan by construction of solar power project.

Technical Scope: The Al-Bageer Project will require the design, engineering, procurement, construction, testing, commissioning, operation and maintenance of a fixed tilted ground-mounted photovoltaic power plant of approximately 10 MWp installed PV power together with associated infrastructure and facilities. infrastructure and facilities. Table 3 shows the metrological data- Khartoum solar project

TABLE 3: METROLOGICAL DATA- KHARTOUM SOLAR PROJECT

Maximum Temperature	50 °C
Minimum Temperature	10 °C
Average Humidity	30%
Pollution level	Normal

Location: The PV Plant will be located in the proximity of Khartoum (approximately 36 km southeast of Khartoum). The average annual solar irradiation rate is high at 2,398 kWh/m2.Theterrain is flat and suitable for PV applications. The total available area for the PV plant is approximately 421,000 m^2

iii. 3 MW Al-fashir Solar Power Project

The aim of this project is to establish reliable electric power supply to Al-Fashir city isolated grid in the west part of Sudan by construction of solar power project.

Technical Scope: The Project will require the design, engineering, procurement, construction, testing, commissioning, operation and maintenance of a fixed tilted ground-mounted photovoltaic power plant of approximately 3 MWp installed PV power together with associated infrastructure and facilities.

TABLE 4: METROLOGICAL DATA- ALFASHIR PROJECT

Maximum Temperature	50 °C
Minimum Temperature	10 °C
Average Humidity	30%
Pollution level	Normal

Location: Al-Fashir city is in the west region of the Sudan at 13°38′N 25°22′E. The PV Plant will be located to the east of Al-Fashir city. The average annual solar irradiation rate is high at2,370 kWh/m^2. The terrain is flat and suitable for PV applications. The total available area for the PV plant is approximately one square kilo-Meter.

iv. 2 MW al Geneina Solar Power Project

The aim of this project is to establish reliable electric power supply to Al Geneina city isolated grid in the west part of Sudan by construction of solar power project.

Technical Scope: The Project will require the design, engineering, procurement, construction, testing, commissioning, operation and maintenance of a fixed tilted ground-mounted photovoltaic power plant of approximately 2 MWp installed PV power together with associated infrastructure and facilities. Table 5 shows metrological data – al Geneina project

TABLE 5: METROLOGICAL DATA – AL GENEINA PROJECT

Maximum Temperature	50 °C
Minimum Temperature	10 °C
Average Humidity	30%
Pollution level	Normal

Location : Al Geneina city is in the west region of Sudan at 13°26′N 22°26′E. The PV Plant will be located to the southeast of Al Geneina city. The average annual solar irradiation rate is high at 2,370kWh/m2. The terrain is flat and suitable for PV applications. The total available area for the PV plant is approximately one square kilometer.

v. 100 MW Wind Power Project in Dongola

The aim of this project is to establish reliable electric power supply to the national grid Northern State by construction of wind power plant.

Technical Scope: The scope is an EPC project shall include survey, soil investigation, design manufacturing, supply, transportation of material to the site, installation and commissioning of equipment's, substation erection, electrical equipment including the related civil works and site supervision. Table 6 shows metrological data (for Dongola)

TABLE 6: METROLOGICAL DATA (FOR DONGOLA)

Maximum Temperature	50 °C
Minimum Temperature	5 °C
Average Humidity	35%
Average wind speed	7.2 m/sec @ 60m agl
Pollution level	Normal

Locations: The Dongola wind farm is located in the northern part of the Republic of Sudan near the village of Dongola, located approximately 460 km north north west of the Sudanese capital of Khartoum.

vi. 20 MW Wind Power Project in Nyala

The aim of this project is to establish reliable clean electric power supply to South Darfur states by construction of Nyala wind power project to support Nyala isolated grid and the future national grid extension.

Technical Scope: The scope is an EPC project shall include survey, soil investigation, design manufacturing, supply, transportation of material to the site, installation and commissioning of equipment's, substation erection, electrical equipment including the related civil works and site supervision. Table 7 shows metrological data - wind power project in nyala.

TABLE 7: METROLOGICAL DATA - WIND POWER PROJECT IN NYALA

Maximum Temperature	45 °C
Minimum Temperature	5 °C
Average Humidity	22%
Average wind speed	7.9 m/s @ 60m agl
Maximum wind speed	34 M/sec
Pollution level	Normal

Location: The nyala wind farm is located in the western part of the Sudan near Nyala city, located approximately 900 Km southwest of Sudanese capital Khartoum.

vii.180 MW Wind Power Project in Red Sea State

The aim of this project is to establish reliable clean electric power supply to Red Sea state and support the national grid by constructing Red Sea wind power.

Technical Scope: The scope is an EPC project shall include survey, soil investigation, design manufacturing, supply, transportation of material to the site, installation and commissioning of equipment's, substation erection, electrical equipment including the related civil works and site supervision. Table 8 shows the metrological data (red sea area)

TABLE 8: METROLOGICAL DATA (RED SEA AREA)

Maximum Temperature	45 °C
Minimum Temperature	15 °C
Average Humidity	62.9%
Average wind speed	7.04 m/sec @ 50m agl
Pollution level	Normal

Location*:* The proposed project's site is located in TOKER Town in red sea state. The site is of area: length of 12 Km and width of 5 Km.

Recommendations

i. Government should consider water pumping wind machines program as infrastructure building program and should encourage village co-operatives or set up co-operation for installing and maintaining wind pumps. They charge for water supplied.
ii. Government should encourage wind energy and solar systems in view of the environmental problem.

iii. To attain exchange of knowledge and information, international promotional groups must be set up with its own office, newsletter and e.g., annual workshop. Moreover, an association with a larger extent, more power and contacts with other energy bodies needs to be established on the long term.
iv. To encourage the private sector to assemble, install, repair and manufacture wind pumps and solar cell via investment encouragement, more flexible licensing procedures.
v. To direct Sudan resources away from feeding wars and the arms industry towards real development, which will serve the noble ends of peace and progress.
vi. Finally, several automatic weather stations that record data on a temporal and spatial basis will be needed. These stations will be considered as complementary to the existing stations and will serve as a good source of information for statistical analyses and correlation among various stations.

CONCLUSION

All of the fundamental criteria for a successful Renewable Energy application are available in the Sudan; however, the contribution of solar & wind energy systems to meeting energy demand in the Sudan is still very low and solar energy application is in the infancy stage often due to the factors for sustainability and replication were missing. 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 solar energy seems interesting. Also, renewable energy development must be taken care of by universities, research centers and by administration within relevant ministries. Research and experiments should be focused on the development of this source to make it economically more competitive with other fossil fuels.

REFERENCES

[1] Abdeen Mustafa Omer, (2015), Evaluation of sustainable development and environmentally friendly energy systems: case of Sudan" E3 Journal of Environmental Research and Management Vol. 6(3). pp. 0237-0261.
[2] Asim Osman Elzubeir (2016), "Solar Energy in Northern State (Sudan): Current State &Prospects", Science PG, American Journal of modern Energy.
[3] Eisa EI. Renewable energy potential and applications in Sudan. In: Proceedings of the round table on renewable energy, 1016 King Street, Virginia, USA.
[4] National Energy Administration (NEA)(1983), Renewable energy assessment for the Sudan. Sudan: Khartoum.
[5] Energy Research Institute (ERI), (1997). Renewable energy resources potential in Sudan. Khartoum, Sudan.
[6] Franz Trieb, Joachim Nitsch, Stefan Kronshage, Christoph Schillings, Lars-ArvidBrischke, Gerhard Kniesb, G. Czisch(2002)," Combined solar power and desalination plants for the Mediterranean region - sustainable energy supply using large-scale solar thermal power plants", ELSEVIER
[7] Jorgenson, J., P. Denholm and M. Mehos (2014), Estimating the Value of Utility-Scale Solar Technologies in California under a 40% Renewable Portfolio Standard, NREL/TP-6A20-61695.
[8] Lenzen, F. (2014), Overview of Parabolic Troughs and Linear Fresnel Receivers, presentation at the IEA workshop on solar electricity roadmaps, Paris, 3.
[9] Nelson, D. and G. Shrimali (2014), Finance Mechanisms for Lowering the Costs of Clean Energy in Rapidly Developing Countries, Climate Policy Initiative.
[10] R.Faranada, S.Leva and V.Maugeri MPPT techniques for PV System; energetic & cost comparison, WSEAS Transactions on Power System, Issue 6,volum 3,June 2008, Italy.
[11] LILIT V. MELIKYAN**, "**Outcome Evaluation in the Practice of Environment and Energy Outcome Evaluation", UNDP Sudan Under CPD 2013-2017 –Final Report, Ministry of Water Resources Irrigation and Electricity, January 30, 2018
[12] Zuhairuse Md. Darus, Nor Atikah Hashim Siti Nurhidayah, Abdul Manan MohdAzhar, Abdul Rahman Khairul Nizam, Abdul Maulud, Othman Abdul Karim. (2009), "The Development of Hybrid Integrated Renewable Energy System (Wind and Solar) for Sustainable Living at Perhentian Island, Malaysia", European Journal of Social Sciences , Vol. 9, Number 4.
[13] University of Khartoum Consultancy Corporation (UKCC) (2016), Feasibility Study of Developing Solar PV Projects in Khartoum State: An Economical Analysis.
[14] International Finance Corporation (2015), Utility-Scale Solar Photovoltaic Power Plants A Project Developer's Guide.

[15] Ika Shinta Mardikaningsih (2016) Techno-economic Feasibility Analysis of a Public Street Light with Solar Cell Power Proceedings of the International Multi Conference of Engineers and Computer Scientists 2016 Vol II, IMECS 2016, Hong Kong.

[16] Peter Acheampong Kwame Nkrumah University of Science and Technology, (2014), Feasibility of using solar PV and light emitting diodes (LEDS) for street-lights in Ghana: a case study of Wenchi Municipality.

[17] University of Upper Austria, (2015), Pre-Feasibility Study of A 1mw PV Plant for Cali, Colombia.

[18] Projects Profiles, Renewable and Alternative Energy Directorate, Publications of the Ministry of water Resources and Electricity, Khartoum – Sudan 2018.