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Solar Energy in Northern State (Sudan): Current State and Prospects

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Abstract: This article discussed present and future situation of solar energy; with special concern to PV technologies, in Northern State (Sudan) as an essential element for the sustainable development of the State. Also, the article identified the constraints that faced the large-scale penetration of solar energy into the energy market of the State, and draw conclusion and recommendation for increasing solar energy contribution to this market.

Keywords: Renewable Energy, Solar Energy Technologies, PV Technologies, Northern State (Sudan)

1. Introduction

Energy is an essential factor in the development movement, since it stimulates and supports the economic growth and development. In recent years, Sudan has increased efforts to exploit renewable energy sources and reduce its dependence on oil [1]. Application of new and renewable sources of energy available in Sudan is now a major issue in the future energy strategic planning as alternative of fossil conventional energy to provide part of the local energy demand. The Government of the Sudan, in cooperation with various international development agencies, had explored the role of traditional and renewable energy technologies in meeting the demand of energy to the rural communities.

There appears to be general agreement that the most significant of the renewable energy sources is solar energy. Solar energy posses 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. Of all energy sources, it is the least encumbered by environmental and safety hazards. And, most significantly, it is possible to collect, convert and store solar energy with present technology. Long-term operating economy is another characteristic of solar energy systems. Solar energy development was taking a long time to become technically viable and economically competitive with conventional energy sources. The main source of energy which applicable in Sudan for rural now is solar energy, and Northern State has been considered as one of the best parts of the Sudan for exploiting solar energy as shown in Fig. 1.

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. A study was conducted to understanding the characteristics and contribution of PV technologies; as one of the solar energy technologies, in Northern State (Sudan) and provided a baseline research on the specific applications to assess the appropriateness of these technologies, and to found out the elements of sustainability within the introduced technologies. For the purpose of this study both secondary and primary data were obtained. The secondary data had been obtained from general literature review and Administration of Energy and Mining within Ministry of Physical Planning, Housing and Public Utilities (Northern State). The primary data had been collected through a visit to some selected locations where solar energy applications were used. Photographs were taken at the selected locations for illustration of both technologies besides its documentation.

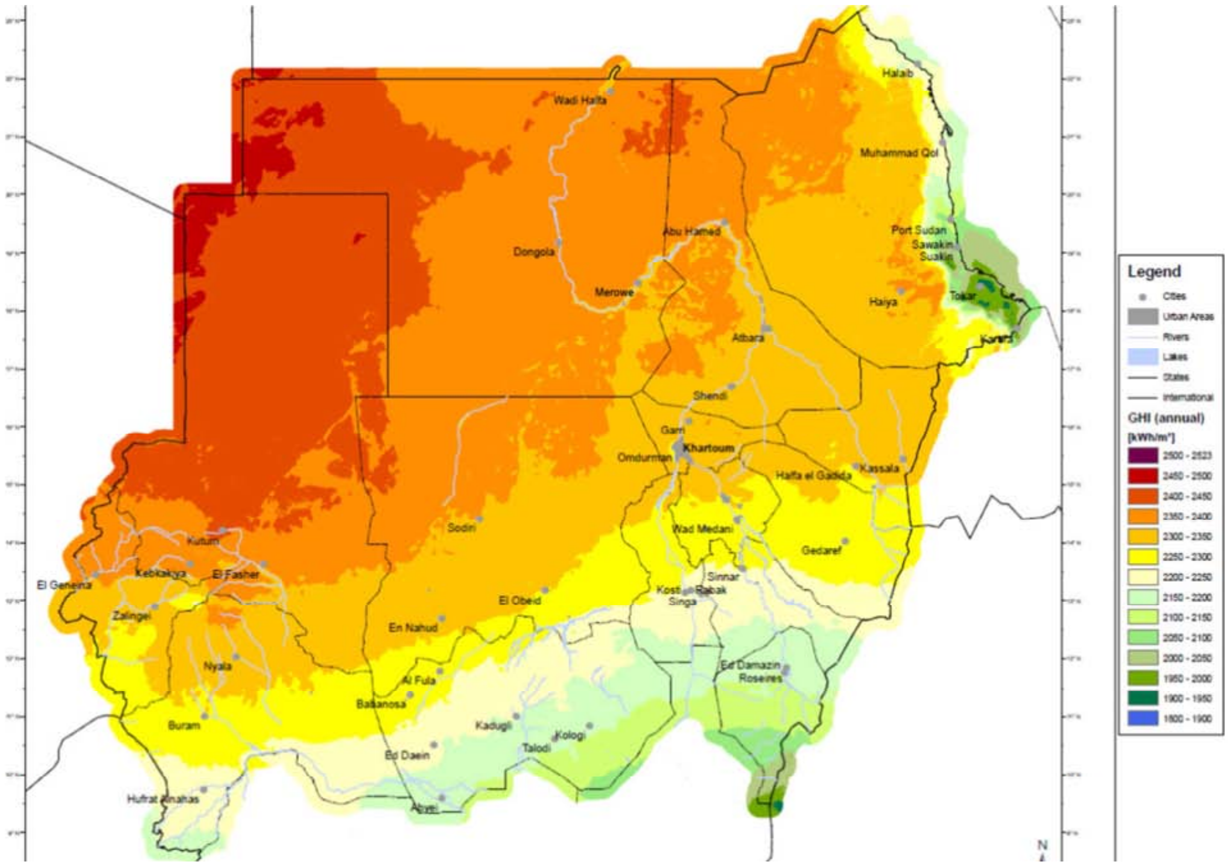

Figure 1. *Solar energy resource available in Sudan (Solar Atlas) [2].*

2. The Potential for Solar Energy in Northern State (Sudan)

Northern State (Sudan) is one of the largest state in the Sudan with an area of approximately 348,765 km^2, and a typical desert climate where rain is infrequent and annual (the sun is rarely obscured by cloud; the main reflection factor of solar radiation). It lies between latitudes16°N and 22°N; and longitudes 20°E and 32°E. The State lies within a high sunshine belt and this has enormous solar energy potentials. Solar energy become more important since there is local resources available and indefinite source of energy in the State.

Northern State is a relatively sparsely populated (2 persons per squared km), the total population according to the 2008 census was 699,065 inhabitants. The State has substantial proportion of its population living in rural area and remote areas; rural people were 556,625 (80% of the total population in the State) and nomads were 13,964 [3]. One of the factors that affect rural development is the restricted and expensive supply of energy, a matter that asserts the importance of renewable energy development as an essential option for sustainable development. Due to the present limitations, and sharp shortages or unavailability of both electricity and petroleum products to rural people, solar system based on utilizing locally available is alternate option to rural development in the State. In order to evaluate the potential for solar energy in Northern State (Sudan), it is important to investigate its current status.

3. Applications of Solar Energy Systems in the State

To evaluate the potential of different solar applications, a clear understanding of the fundamental criteria of success is obviously a first requirement [4]:

Criterion 32: Energy demand:

The energy demand should be important enough, micro-economically speaking, to justify investment costs in a solar system for the individual user. At the same time, the macro-economic importance should be sufficient, in order to justify the development of solar systems.

Criterion 32: Energy supply:

Obviously the chances for the successful application of a solar system are greater in a climate with greater amounts of solar radiation.

Criterion 32: Solar system efficiency:

High radiation intensity values greatly contribute to solar system efficiency. Thus the climate can have a significant influence on efficiency.

Criterion 32: Solar system cost:

Spreading the use of a solar system over the whole year rather than over just a few months. In evaluating the solar system cost versus performance, its feasibility should be compared not only with the conventional system, but with all the other alternatives.

Criterion 33: Socio-economic outlook:

Different elements can play a crucial role here, e.g. the attitude of the users towards this new technology, the size and the degree of intensity of the populations. In this same socio-economic context it is appropriate to stress the widely recognized desirable aspects of solar system from the environmental point of view.

Small villages, particularly the isolated ones and/or low population density, are the most appropriate location for solar applications because conventional supplies of electricity are both difficult and expensive to provide it to these villages. Campen et al. [5] suggest that, photovoltaic technologies has been often shown to be the most effective solution for improving such services in remote, un-electrified areas. The PV system includes a solar system consists of a photovoltaic solar panel; which convert the suns energy into electricity form depending on a propriety of certain semi-conductors; such as silicon, cadmium sulfide and gallium arsenide, battery, charging controller and end uses.

Grothoff [6] reported that, countries in Africa with the highest PV potential include among others, Sudan. Solar PV applications in Sudan started as early as 1970 [7]. PV technologies have a number of applications relevant to rural use in Northern State (Sudan). These include among others, electricity generation, PV pumping, telecommunication network, vaccine refrigeration for human and animal use, traffic lighting and lighting of road sign, over-speed detection on high ways, security services, schools power supply, rural health clinics, community centers and clubs, mosques and *khalwa(s)* lighting.

A Field survey to selected locations showed that, the operators of the installed systems were certain people who were assigned to do the job, depending on where the utility was installed. Battery replacement and disposal were serious problems. Solar panels sited at ground level became dirty more quickly. Dust deposition on PV panels caused degradation of PV panel's performance and energy yield losses [8], in the same manner other particulate accumulation (e.g. birds residues) causes on PV panels transmission loss [9]. Also, there were cracks seen on the upper cover of solar panels in some sites. Solar panels mounted near ground were more susceptible to damage by animals or children. This necessitates both periodic cleaning and maintenance of the solar panels. The major problem was that solar energy technologies require high initial capital cost. Most of this capital cost for implementation of these technologies was provided by a number of international aid programs. The sustainability of most the project was not achieved and these projects had stopped after cessation of foreign funding.

All of the potential uses of PV technologies are too numerous to include here, therefore, only some of the more important uses are mentioned, especially those that have been demonstrated successfully. The current contribution of solar energy systems to the energy sector in the State include:

3.1. Rural Electrification

Table 1. presents the main sources of energy for lighting in the State, it cleared that 45% of the households doesn't used public electricity as energy source for lighting, major of these percentage is in rural area. The lack of electricity raises a lot of negative effects that dramatically limit a community's potential rate of growth, as well as residents' basic quality of life [10].

Table 1. *Main sources of energy for lighting in the State [11].*

Source of lighting	No. of households (%)
Without lighting	1
Candle	2
Wood	1
Kerosene lamp (lantern)	14
Generator	27
Public electricity	55

In recent years attention has risen again regarding the issue of rural access to electricity supply and regarding the relation between energy (electricity) and poverty. Rural energy is generally recognized as an important element of rural socio-economic development [5]. Therefore, Barrier Removal to Secure PV Market Penetration in Semi-Urban Sudan Project (PVP) was started in 1999 and spreads over 12 states; included Northern State, to remove the barriers that hindered market penetration of PV applications in general and households in particular. The PVP funded jointly by UNDP, the Global Environment Facility (GEF) and the Government of Sudan [12]. Generally, the project focused on dissemination of photovoltaic systems with emphasis on provision of electricity for small-scale applications to satisfy the first assessed need.

The Northern State is large and sprawling, and has too Nile Islands and vast arable land. Therefore, solar electricity can be used for power supply to remote villages and locations not connected to the national grid. The main lighting systems using solar energy were installed in mosques and prayer rooms (*Zaoya(s)*), schools, health centers, clubs, security points and miscellaneous (some houses of authorized persons, official offices, *Khalwa(s)*,etc.). Through PVP many such systems had been installed in the State and an achievement for improvements in social interaction was maintained. Number of solar panels in each system is illustrated in Fig. 2; the largest number of systems is consisted of two solar panels for small uses.

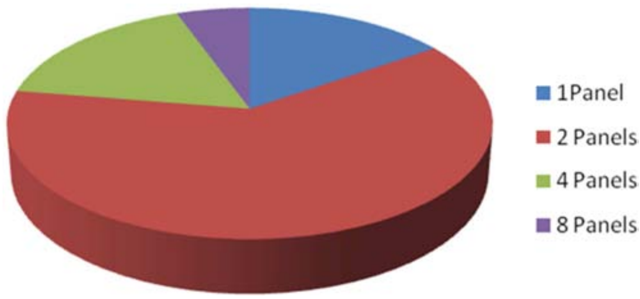

Figure 2. *Number of solar panels in solar energy systems [13].*

Also, Fig. 3. Shows the distribution of solar energy systems in the utilities, amajor part of the systems is used for operating of amplifiers and lighting of mosques and prayer room (*Zaoya(s)*) followed by schools power supply and health centers.

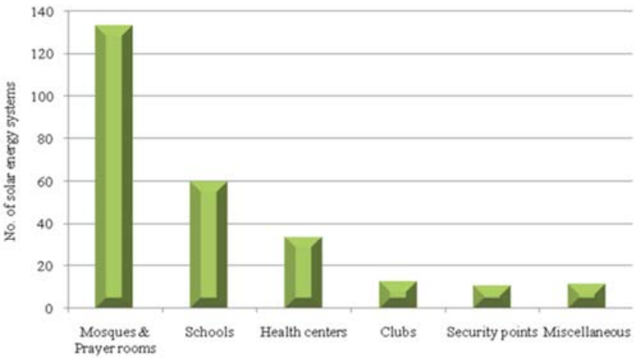

Figure 3. *Distribution of solar energy systems in the utilities [13].*

3.2. Drinking Water

Interest on PV pumps emerged after the United Nations declared 1981-1990 as the "Decade for Water". As efforts to enlarge supplies of usable water continue PV pumps were described as being simple, not complicated and is both useful and economical viable in many areas of the world [14]. Water pumping for domestic use can be considered as one of the basic needs in the rural areas. The size of the PV system is directly dependent on the size of the pump, the amount of water that is required and the solar irradiance available.

For the favourable solar radiation conditions; as in Northern State, solar water pumping may be a competitive application against diesel-driven pumps for remote areas [15]. LeBel [16] examined both traditional diesel and alternative renewable energy technologies for providing potable water to village communities in the Sudan, based on a number of technical and economic assumptions he found that, the cost-effective of solar technology is sensitive not just to underlying discount and foreign exchange rate consideration, but also to the pricing of traditional diesel fuel in the Sudan. Also, he stated that, the current system of multiple pricing of diesel fuel to be inefficient and those renewable technologies can play a role in selected settings once one adopts economic pricing.

A typical solar powered pumping system consists of a solar panel array that powers an electrical motor, which in turn powers a bore or surface pump. The water is often pumped from the ground into a storage tank that provides a gravity feed, so energy storage is not needed for these systems. Figure 4. demonstrates the use of solar energy for water pumping in Alkhwei School in Alselaim Area, the system consists of six series and four strips in parallel (24 solar panels).

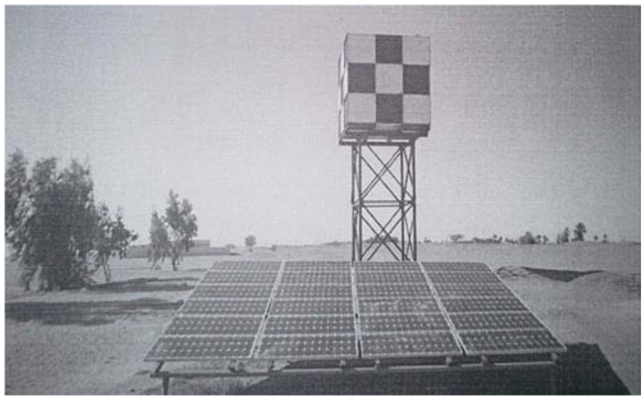

Figure 4. *Solar water pumping of Alkhwei School in Alselaim Area.*

3.3. Irrigation Water Pumping

Agriculture is the backbone of economic and social development in the State, 41% of the households in the State are agricultural households [11], and all other sectors are largely dependent on it. In Sudan, agricultural sector consumed 2.5% of the total energy consumption (28% from electricity, 14.8% from fossil fuels and the rest from biomass fuel) [17]. Goswami [18] stated that, of the total energy used in the agriculture, 12% is consumed by irrigation. Therefore, irrigation is the highest energy-consumed on-farm activity among those which require direct energy input. Electric energy and diesel fuel are various types of energy which are commonly used in irrigation.

As elsewhere in Sudan, diesel systems had been for some time a primary method for small-scale irrigation pumping in the State. Most of the agricultural schemes are located away from the high and low pressure lines, thus the cost of providing electricity in the traditional manner is very high, forcing farmers to depend entirely on diesel-powered water pump. Irrigation water pumping consumers traditionally make technology purchasing decisions on the basis of capital rather than life cycle costs, which imply an implicitly high private discount rate. When life cycle costs are taken into consideration, renewable energy resources can be a cost-effective alternative to diesel pumping systems [16]. Solar water pumping system consisting of four basic units: a PV array, a battery, a DC motor and pump. Solar pumps are used to pump water from boreholes or from surface water to replace diesel engines in the predominant irrigation areas to avoid fuel problems (e.g. uncertain availability and skyrocketing prices). A variety of pump systems and sizes are available from manufactures worldwide. Water tanks are optional, but enable storage of water for gravity pumping on demand.

The Central Forests Nursery in Dongola; follows to the Forests National Corporation (Sudan), used solar pump since 1994. The solar system composes of six series and four strips in parallel (24 solar panels) as shown in Fig. 5. The system has submersible pump used to pump water from borehole, which can irrigate three feddans per day. There are no batteries; therefore, the operating hours is only during the day light.

Figure 5. *Solar system of the Central Forests Nursery (Dongola).*

AbdelGadir and Hammad [19] examined the technical and economical feasibility of solar photovoltaic pumping of water for agricultural application in nine selected sites in Sudan; included village near Dongola (Northern State), they concluded that solar water pumping is suitable technically and economically, and even better than the diesel pumping systems in the selected sites.

Comparing with conventional fuel, solar water pumping system has numerous advantages, for instance, beside of no cost for fuel and maintenance, the system has no noise and pollution for the environment. Although there are solar water pumps with high capacity, usually the pumps that are used in remote areas are small scale one [20]. Also, a solar PV system can be used for delivering water for drip irrigation system. Mahmoud and Nather [21] concluded that, solar photovoltaic water pumps are operating more effective than other traditional water pumping systems (water pumped using conventional gird connected and diesel powered pumping methods) for drip irrigation systems.

The Government of Sudan and the United Nations Development Programme (UNDP) work to prepare of solar energy-powered pumps project for irrigation in the Northern State [22]. The idea behind the project is to replace the diesel-powered water pumps currently used in agricultural schemes with solar energy-powered ones. The project includes installation of 28 solar energy pumps to be used as illustrative field, for introducing farmers to the functioning of solar energy pumps, and for training on pump's operation and maintenance in both the public and private sectors. The second phase of the project consists of implementation of 1422 units within the next 4 years starting 2015.

3.4. Lighting of Road Sign

A solar lighting system of road sign in the exit of Dongola-Alselaim Bridge towards Alselaim; which was initiated in a year 2009, consists of five series and two strips in parallel (10 solar panels) as illustrated in Fig. 6. This system is not working now, but this has nothing to do with the difficulty of fixing the defect. Rather it might be attributed to the failure to avail the maintenance services and lack of trained technicians at the area.

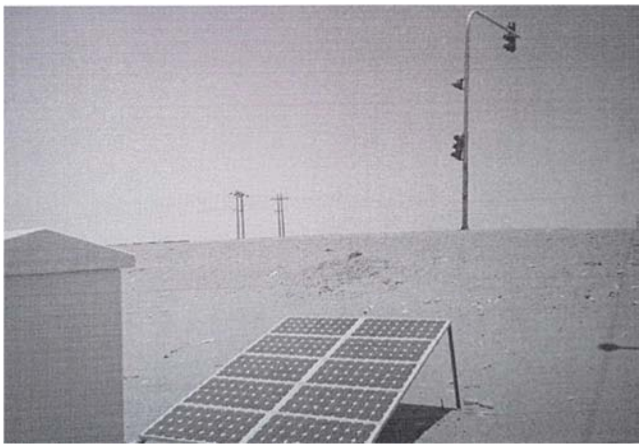

Figure 6. *Solar system of road sign of Dongola- Alselaim Bridge.*

3.5. Traffic Lighting

The solar lighting system of Aldebba- Argi Bridge is shown in Fig. 7; the system was installed in a year 2011 and is still working properly. Two small solar panels were supported on the top of each lighting pole.

Figure 7. *Solar lighting system of Aldebba- Argi Bridge.*

3.6. Other Applications

Solar energy is used in Dongola International Airport as power supply by General Authority of Civil Aviation since 1997. Two systems were found, the first one consists of 8 series and 14 strips (112 solar panels) with batteries mounted on the top of building, and is used to operate extended range VHF communications devices in aerodrome control tower as in Fig. 8.

Figure 9. Shown the second solar system which composes of 100 solar panels with batteries mounted near the ground, and is used to operate radio navigation station for aircraft (VOR/DME).

Figure 8. *Solar system in Dongola International Airport Aerodrome Control Tower.*

Figure 9. *Solar energy system to operate radio navigation station for aircraft in Dongola International Airport.*

4. Problems and Constraints Faced the Dissemination of the Solar Energy Application

Factors affecting development, diffusion and adoption of solar energy technologies in the State include:

1. Low awareness among both consumers and decision makers about the potential benefits of renewable energy technologies due to insufficient dissemination of information.
2. Inadequate technical services and inadequacy of training, including the difficulty of maintenance and unavailability of spare parts.
3. Lack of monitoring and proper evaluation for the previous disseminates solar energy technologies to assess their impact and identify the barriers (success-failure).
4. Lack of any governmental incentives supports for the interested users of solar energy technologies.
5. Lack of appropriate financial systems to promote solar energy technologies dissemination for both public and private sectors.
6. Lack of encouraging investment laws and regulations attract more private companies and small entrepreneurs to be involved in dissemination and commercialization of solar energy technologies.
7. Lack of proper studies on the impacts of solar energy technologies, socially economically and environmentally and the importance of self-dependency.

5. Prospects of Solar Energy Technologies in the State

Northern Sate has immense untapped solar resources for energy production. The use of renewable energy like solar is important for the future development of the State. Solar energy is considered a viable solution to the energy challenges of Northern State (Sudan); especially in the rural areas of the State, and to restrictions posed by the rising cost of conventional traditional energy. Therefore, the introduced solar energy technologies have a good opportunity to involve in the energy market in the future prospects. Government has essential role to play in the future of solar energy. A government-financed economic trade-off program may be necessary to encourage greater use of solar energy, since high start-up costs coupled with lack of financing mechanisms is more problematic, which is why these systems are not yet widely spread.

6. Conclusion and Recommendations

6.1. Conclusion

All of the fundamental criteria for a successful solar application are available in the State; however, the contribution of solar energy systems to meeting energy demand in the State 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 being 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.

6.2. Recommendations

1. Develop a viable institutional plan for commercialization of solar energy systems through demonstration seminars and workshops not only to potential users but also to distributors and the public at large.
2. Encourage the rural people to use solar energy technologies instead of conventional energy by providing incentives from the government. Also,

government should encourage solar energy systems in view of the environmental benefit.

3. Encourage training opportunities to personnel at different levels.
4. Availability of fund for maintenance of solar systems and administration for maintenance responsibility.
5. Encourage the private sector to assemble, install, repair and manufacture of solar energy devices.
6. Promote research and development, demonstration and adaption of solar energy.

References

[1] Omer A. M. 2001. Renewable Energy Potential in Sudan. International Energy Journal, 2(1): 15-35.

[2] Saied Y.A. 2015. Renewable Energy Current Projects and Future Plans. 9th German-African Energy Forum, Hamburg, May 4th-5th, 2015.

[3] Central Bureau of Statistics. 2009. 5th Sudan Population and Housing Census- 2008: Priority Results, Northern State.

[4] Goedseels V., Stuyft E. Van Der, Avermaete U., Buis H. and Palz W. 1986. New Perspectives for Energy Savings in Agriculture, Current Progress in Solar Technologies Vol. 2. Dordrecht: D. Reidel Publishing Company.

[5] Campen B. Van, Guidi D. and Best G. 2000. Solar Photovoltaics for Sustainable Agricultural and Rural Development. Environment and Natural Resources Working Paper No. 2, FAO, Rome.

[6] Grothoff J. M. 2014. Estimating the Renewable Energy Potential in Africa. International Renewable Energy Agency (IRENA).

[7] Sayigh A. 2016. Renewable Energy in the Service of Mankind Vol. 2, Selected Topics from the World Renewable Energy Congress 2014. Springer International Publishing, Switzerland.

[8] Sayyah A., Horenstein M. N. and Mazumder M. K. 2014. Energy Yield Loss Caused by Dust Deposition on Photovoltaic Panels. Solar Energy, 2014(107): 576- 604.

[9] Sarver T., AlQaraghuli A. and Kazmerski L. 2013. A Comprehensive Review of the Impact of Dust on the Use of Solar Energy: History, Investigations, Results, Literature, and Mitigation Approaches. Renewable and Sustainable Energy Reviews, 2013(22): 698-733.

[10] Fog D. 2014. Sustainable Energy Solutions for Rural Areas and Application for Ground water Extraction. Global Energy Network Institute (GENI).

[11] Central Bureau of Statistics. 2009. Poverty in Northern State: Estimations from National Baseline Households Survey 2009.

[12] El-Hadi A. 2016. The Photovoltaic Project of Sudan to Reach More than One Million Homes: An Exercise in Policy Making, Finance, Strategies, Education and Sustainability. Renewable Energy in the Service of Mankind Vol. 2, Springer, pp 551-560.

[13] Administration of Energy and Mining, Ministry of Physical Planning, Housing and Public Utilities (Northern State). 2016.

[14] Elsayed SH. N. 2009. Problems and Prospects of Solar Energy Technologies in Rural Development- Case of North Kordufan State (Sudan). Ph.D. Thesis. University of Khartoum, Sudan.

[15] Hamza A. A. and Taha A. Z. 1995. Performance of Submersible PV Solar Pumping under Conditions in the Sudan. Renewable Energy, 6(5): 491-495.

[16] LeBel PH. 2001 An Economic and Financial Analysis of Rural Water Supply Technologies in the Sudan. Center for Economic Research on Africa, School of Business, Montclair State University, New Jersey.

[17] Omer A. M. 2006. Energy Consumption, Development and Sustainability in Sudan. Sudan Engineering Society Journal, 52(47): 35-43.

[18] Goswami D. Yogi. 1986. Alternative Energy in Agriculture Vol. 1. Boca Raton: CRC Press, Inc.

[19] AbdelGadir E. K. and Hammad M. A. 2014. Technical and Economical Feasibility of Solar PV Pumping of Water in Sudan. Available at: http://www.eacademic.ju.edu.jo/.../Technical_and_Economical_Feasibility_of_Solar_PV_Pumping_in_Sudan.pdf.

[20] Gopal C., Mohanraj M., Chandramohan P. and Chandrasekar P. 2013. Renewable Energy Source Water Pumping Systems- A Literature Review. Renewable and Sustainable Energy Reviews, 25(2013): 351-370.

[21] Mahmoud E. and Nather H. 2003. Renewable Energy and Sustainable Developments: Photovoltaic Water Pumping in Remote Areas. Applied Energy, 2003(74): 141-147.

[22] UNDP in Sudan. 2015. Onto the Future: Solar Energy in Sudan (Serving the Environment, Development and Agricultural Sectors). Available at: http://www.sd.undp.org/content/sudan/en/home/ourwork/environmentalenergy/sucessstories/Solar_Energy_in_Sudan.html.