# The Future of Solar Energy in Sudan: Opportunities and Challenges

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**Abstract**
This opening article Spots a green light on the applications of solar energy and the role that solar energy can play to enhance the economic development in Sudan. The empirical data gained from the different focus group discussions (FGD, different countries statistics from the International Renewable Energy Agency(IRNEA) and the set of innovative Economics/ technical ideas learned of developed countries were used to thoroughly articulate and explain the opportunities and challenges of the future of the solar energy in the Sudan. It's concluded that, a comprehensive effort is needed form individuals, governments sectors, policy makers and civil societies across the country to encourage and support the making use of the solar-based electricity.

Keywords: International Renewable Energy Agency, Solar Energy, Solar Microgrid, Solar Grid Connected,

## 1. Introduction

Solar system is one to the most clean and easy renewable source of energy which is clean, unlimited, and free. Solar energy is available and easy to use in the far remote areas. Solar energy can be converted to electricity by using photovoltaic cells and thermal panels. photovoltaic cells can arranged to construct a photovoltaic panels. These panels produce a direct current of electricity (DC power). This Dc current can be easily inverted to alternating current electricity (AC power) to be used in various applications. Today, in addition to solar system and other renewable energy-such as wind, biofuels and Hydro play a key role in creating a clean and reliable future energy. The benefits from these sources are many and varied, including a cleaner environment and less cost. Classically, electricity is often produced by burning fossil fuels such as oil, coal, and natural gas. The combustion of these fuels releases a variety of pollutants into the atmosphere, such as carbon dioxide ($CO_2$), sulfur dioxide ($SO_2$), and nitrogen oxide ($NO_2$). These pollutants create acid rain and smog. Furthermore, Carbon dioxide from burning fossil fuels is a significant component of greenhouse gas emissions. These emissions could notably alter the world's environment and contribute to global warming problem.
Renewable energy, on the other hand are clean energy resources. In fact today using renewable energy to replace the conventional fossil fuels sources can prevent the release of pollutants into the atmosphere and help combat global warming problem. For example, using solar energy to supply a million homes with energy would reduce $Co_2$ emissions by 4.3 million tons per year[1]. In work elaborates the opportunities and challenges of the deployment of Solar energy in Sudan. The rest of the paper is organized as follows: section 2 explains the main solar system practical setup. Section 3 elaborates the key economical opportunities of solar energy to the country. Section4, draw attention to the main challenges facing the deployment of solar system at a large scale and section 5 Conclude the paper.

## 2. Main Design and setup

Today there are a number of solar installation methods for the different services. It is important to select the best and suitable solar configurations for specific application/services. This section illustrates and explains the different solar system configurations methods explicitly: grid connected Solar system, Solar in Microgrid and standalone directly connected to customer

### 2.1. Grid-connected Solar System

A grid-connected photovoltaic system or grid-connected PV system is an electricity generating solar PV power system that is connected to the utility grid. Atypical grid-connected PV system consists of solar panels as shown in figure 1, one or several inverters, a power conditioning unit and grid connection equipments. They range from small residential and commercial rooftop systems to large utility-scale solar farm power stations. When conditions are right, the grid-connected PV system supplies all it is power to the utility grid. Today in India a lot of grid connected systems are in operations [2-4]. In sub-division of grid-connected PV system the solar system is basically used to energize small residential and commercial load services and the excess power, beyond consumption by the connected load is connected to the utility grid as reported in [5-7]

Figure 1. Example Solar panels of Grid-Tied System/On-grid system of Elfashir Solar farm (5 MW Capacity Project)

### 2.2. Solar Microgrid

A solar microgrid is a renewable energy system that acts independently of the main grid, although can also integrate and interact with the main grid when it wishes[8]. Micrograds are extremely beneficial to communities that need reliable renewable energy sources. Using a Microgrid will result in greater stability for community power systems, due to its ability to isolate itself from the main grid which can come under attack from natural disasters and an electrical fault. Microgrids will also be especially beneficial to communities where people don't have access to electricity such as India and Africa and in remote places that are prone to natural disasters. Figure 2, shows a typical microgrid Configuration as widely deployed in a lot of developing countries such as Bangladesh, Pakistan, Indonesia and a lot of countries in Africa[9-12].

Figure 2. Typical Microgrid configuration as widely deployed in a lot of developing countries such as Bangladesh, Pakistan, and Indonesia and a lot of countries in Africa [13]

## 3. Key Opportunities

Despite huge strides over the years, about 60% of Sudan population still lack electricity, with at least millions of the un-electrified living in close proximity to the grid. The government has traditionally relied on centralized grid expansion efforts to improve access, but a large part of this problem is due to the small, remote nature of the hundreds of thousands of communities, which increases the cost barrier for electrification strategies to overcome. In the today's world, Electrification is a gateway a lot of basic services such as access to clean water, basic healthcare, education and telecommunications. On the hand, the availability of energy and contribute a lot toward the well-being people by facilitating the basic economics activities such as agriculture and agriculture related industries. This section elaborates the key opportunities and surplus of solar energy the whole country.

### 3.1 Boosting The Overall Country Generation Capacity

According International Renewable Energy Agency (IRENA), PV is one of the fastest-growing renewable energy technologies, and is ready to play a major role in the future global electricity generation. As explained in previous section PV installations can be combined to provide electricity on a commercial scale (grid connected), or arranged in smaller configurations for micro-grids or personal use. Figure 3. shows the trend of the cost of the *kwh* of solar energy in China, Turkey and Germany in the last decade. The chart reveals that the cast the *kwh* generated from Solar system decrease toward the frontier of the kwh generated from the fossil fuels.

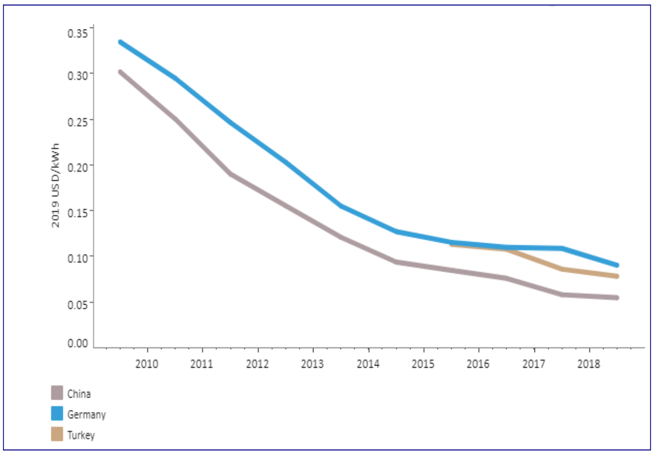


Figure 3, Solar Energy Cost in USD/kwh, Source International Renewable Energy Agency (IRENA)[14]

Due to this decrease in the cost trend, the solar energy generated in a lot of countries increased dramatically. Figure 4. Shows the total solar energy installed in Egypt increased from *200MW* in 2017 to *1600MW* in 2020, while in turkey the installed solar energy generation increased from *3500MW* in 2017 to *7000MW* in 2020 as shown in figure 5[14].

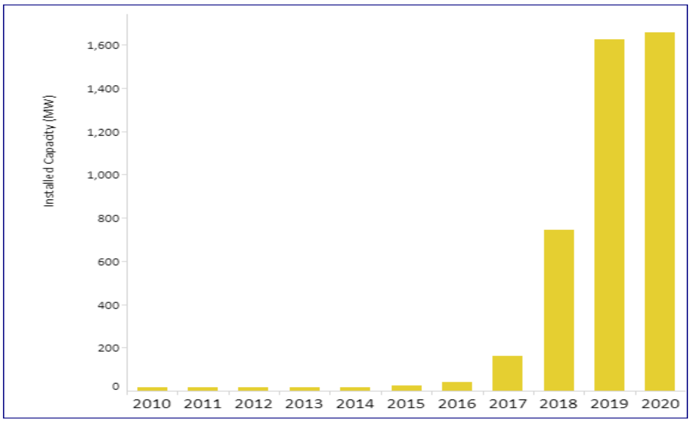


Figure 4. Installed Capacity Trends for Egypt, Source International Renewable Energy Agency (IRENA)[14]

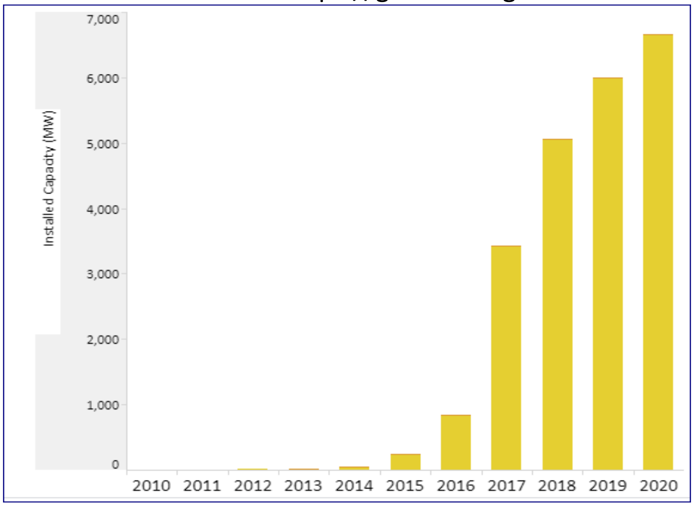


Figure 5 Installed Capacity Trends for Turkey, Source: International Renewable Energy Agency (IRENA)[14]

In contrast, figure 6. Show that the installed solar energy capacity in Sudan increased from *13MW* in 2017 to *18MW* in 2020[14]. This figure reveals that the country overlooks and fails to see the surplus of solar energy. In fact, given the excellent location of Sudan, the country has good opportunity to install large solar power station farms connected to the national grid to energize its economics. Furthermore, there are also excellent chances of using solar PV to power micro-grids to bring electricity access to people who do not live near power transmission lines in remote areas.

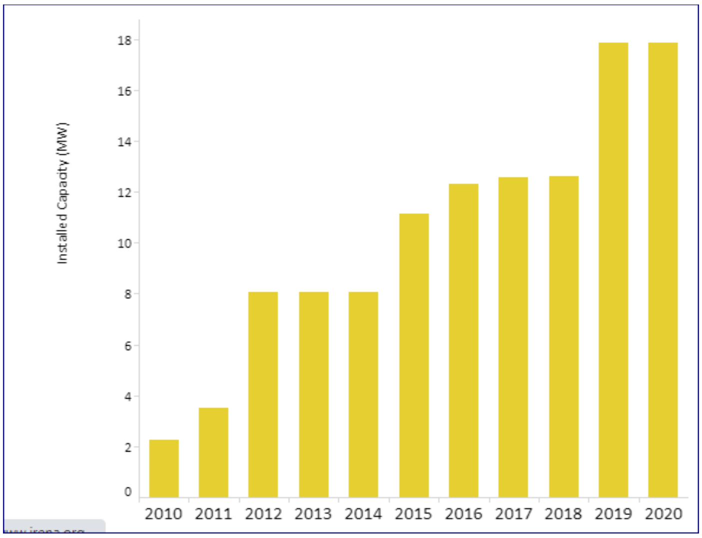


Figure 6. Installed Capacity Trends for Sudan, Source: International Renewable Energy Agency (IRENA)[14]

### 3.2 Connecting Unfortunates far Communities to the ICT Infrastructure

Decentralized renewable energy facilities such as standalone solar home systems and minigrids can provide alternative cost options for electrification problem. Community minigrids typically serve rural communities where the national grid is unlikely to arrive in the near future. They are difficult to get to and even more difficult to observe over long periods. It's no wonder, then, that they have struggled to find traction in national governments and investment options. Recently a lot of studies revel the accelerated shift towards using solar technology to meet the digital divide and close the ICT gap between urban areas and the far remote areas were published. These studies sows that the access to ICT tools in local far communities has risen, with infrastructure that has completely changed the way of life and economic trends. These studies conclude that the use of ICT-based devices has opened a new window for remote communities, where solar energy has made great contributions [15-19]. In this regards ICT/Solar energy technologies will enhance and facilitate the use of the following applications as show by the ITU model given in figure 7.

- e-Agriculture applications (communicating and supporting efficient and productive farming skills and capabilities among farmers. Also, ICT can make rural communities more resilient from both economic and nutritional points of view. Additionally, a specialized mobile app could be provided for example to help farmers detect and treat pests in a timely manner, based on image processing analysis of photos) .
- e-Educations and e-learning (solar energy can facilitating the community access to open and distance learning opportunities to improve the capacity building for teachers and education administrators as well as providing equitable access to quality literacy, lifelong learning and technical skills programs for children, youth, and adults. Furthermore, Local teachers and educators could improve their qualifications and experiences of their students by using engaging education content).
- e-Health applications( solar energy can provide an option to make use of telemedicine and mHealth services to improve access to diagnosis, reducing the cost of the healthcare system access)
- Facilitate the e-government(with solar energy remote people can communicate the important government services and applications such as financial services and hazard risk monitoring, alert, …etc)

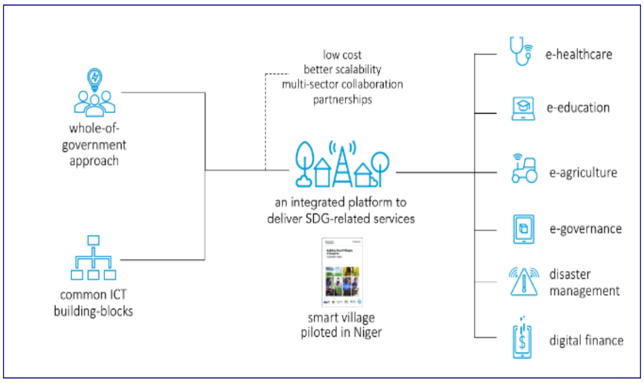


Figure 7. ITU model of applications to connect Smart Remote area

### 3.3 Providing Easy Access to Clean Water for Remote Areas

The ability solar system to provide continuous power in any environment makes it perfect for water pumping in remote areas in a lot of countries all over the world. Today, off-Grid PV systems is the best long term solution with the best cost-performance ratio. At this moment, Solar-powered systems a shown in figure 8. Which demonstrates one of the viable alternatives that have attracted considerable attention for water pumping for remote far areas in Sudan. They have been deployed in many remote areas for clean water for humanity and livestock. Although photovoltaic (PV) systems generally have a high investment cost, it has many features which make it attractive as an alternative source of power for water pumping for remote areas as deployed in many countries around the worlds[20-24].

Figure 8. solar energy for Clean Water[25]

### 3.4 Rural Areas Electrification

Remote areas access to electric power supply has always had a significant role in promoting improvements in all the society sectors, yet nowadays according to finance minster of Sudan interview, over 60% of the people of Sudan still do not have electricity access. Moreover, most of the people live in rural areas which are often isolated, scattered populated and characterized by poor infrastructure and services. In this situation, the growing consideration towards the target of widespread access to energy has emphasized the role of rural electrification plan, and off-grid small-scale generation setup (Microgrid) represents one of the most appropriate options as considered by a lot of developing countries[26-31]. Figure 9 illustrates Learning example using Mirogrid for rural areas electrification[32]

Figure 9. Solar energy for Rural Areas Electrification ( Simple Microgrid)[32]

### 3.5

### 3.6 Solar Energy for Agriculture

Divided by the Nile and rich in fertile land, Sudan's agricultural opportunities are vast, and a lifeline for poverty alleviation and the country's troubled economy. Agriculture offers significant opportunities in Sudan but often relies on diesel-powered water pumps. Recent studies shows that introducing solar technology has increased land use & productivity by nearly 50%[33]. Today Photovoltaic (PV) water pumping systems may be the most cost-effective water pumping option in locations where there is no existing power line[34]. They are also exceptionally well suited for grazing operations to supply water to remote pastures[35]. In practice, simple PV power systems run pumps directly when the sun is shining, so they work hardest in the hot summer months when they are needed most. Generally, batteries are not necessary because the water is stored in tanks or pumped to fields and used in the day time [36-39].

Figure 10. Solar energy for Agriculture[40]

## 4 Key Solar Energy Challenges

### 4.1 Perceived the usefulness of the Solar Technology

Technology usefulness model was defined by Fred Davis as "the degree to which a person believes that using a particular system would enhance their job performance". It means whether or not someone perceives that technology to be useful for what they want to do. Perceived ease-of-use (PEOU) – Davis defined this as "the degree to which a person believes that using a particular system would be free from effort" (Davis 1989). If the technology is easy to use, then the barriers conquered. If it's not easy to use and the interface is complicated, no one has a positive attitude towards it. To this extend extensive PEOU media programs are needed all over the country considering all solar energy Projects stakeholder name the Policy makers for the key Economics/ services Sectors, NGOs and rural Societies. To increase the number of solar technology users, The important messages and tips to be communicated are: Solar energy Technology is very simple, Cost effective, and efficient and has high economic return value to the individuals and the country as whole. Generally, people will have appositive attitude and intention to use the solar technology if they value its benefits and perceive it simplicity. However, the perception may change depending on age and gender because everyone is different.

### 4.2 Technical Issues for Further Research Investigation

Although, solar technology cost is going down dramatically in last decades, there a lot of open issue for further research and investigations. The following list elaborates the important research issues connected to the deployment making use of solar energy at large scale.

- Development of small scale energy management system for small microgrid [41]
- Predicting the exact Solar Energy Generation [42-44]
- Using of solar system Frequency regulation and control [45-47]
- Selecting the optimal PV/Battery size of the system[48-51]
- Optimal planning of solar generation system[52]
- Long term performance, losses and efficiency analysis of solar system[53, 54]
- Using Solar system to improve the power quality in the power utility[55, 56]

### 4.3 Solar Project Finance and Managerial Framework

Given the excellent foreseen economical and social benefits of solar energy and the considerable dropped in the hardware cost solar energy facilities in the past decades, large-scale solar deployment in Sudan Facing a significant financing challenge. This is due to the fact that the majority of lifetime costs associated with solar deployment are the upfront costs incurred at the time of construction (the initial cost or the capital expenditure of the project). As a result, innovation in "finance, management and commerce solutions to expand the access to a capital investment should be the major focus of the government in the near future. In addition to the classical power systems, projects finance methods, This section shortly summarizes the important innovative ideas to expand the deployment of solar energy system. In this regard, the following pioneering ideas were introduced:

- Introduce the practice of community shared solar (CSS) model launch by the US government. CSS Model allow multiple electricity consumers, often in close geographic proximity, to collectively finance an offsite or centralized solar project by purchasing shares or subscriptions to power generated by the project. In practice, among other economical benefits, Participants who finance the development of a CSS project receive compensation for electricity generated by their project [57-64]. In fact, projects within a CSS program may be owned by a utility, a third party, a special-purpose entity created by a utility or by customers, or a charitable nonprofit. Ownership models have direct implications on how a project is financed.
- Introduce the structure of nonprofit solar organization (NPS) reported in [65] to speed up the rural areas electrifications and solar for water pumping Projects

### 4.4 Training and Capacity Building

In developing countries such as Sudan, there are lack of enough individual technical training and appropriate social preparation on using new technology such as solar system. The end user interacting with the new technology will often resulted in project failures due to poor maintenance, abuse, poor installation, and lack of understanding by the system owner, operator or local technician. Today, a lot of research was aimed at investigating the importance of individual training in capacity building programs for solar home system (SHS) technology transfer projects. The focus these studies are on the analysis of the effectiveness of the individual training component in various projects in the Philippines. A survey has been undertaken which included a series of SHS site visits and individual surveys with system owners and operators, and Focus Group Discussions with other project stakeholders. Survey results show that adequate user and local technician training is an important factor in successfully implementing rural electrification through PV power systems. However, for training to be successful there must be a consensus of what the target performance behaviors should be and how they should be measured. The most basic requirements for successful training are that the training reaches to the right people at the right time and delivers the right content.

## 5 Conclusion

This work explains the potential of solar energy to drive the modern economics and highlights the gap of the making use and deployment of solar system in Sudan. The paper also spot the light on the key opportunities and challenges of making use of it at large scale to boost up the overall county electricity generation capacity.

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