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Review

Review of photovoltaic energy access for sustainable growth in the agricultural sector: Economic, market and employment opportunities for rural communities of Sub-Saharan African

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Abstract: Photovoltaic solar energy is one of the immaculate non-pollutant origins of inexhaustible sources of energy. As a result of the increase in energy demand and the bad effects of carbon-containing fuels on the world environment, several nations reflect on photovoltaic solar energy as the appropriate and possible choice for electrification in rural agriculture applications and household practices. To satisfy the increasing electrical energy need and reduce the production of gas. The use of photovoltaic energy cannot be overemphasized in agricultural applications in rural areas. Photovoltaic and electrification in agriculture is the formation of photovoltaic production of electricity, heat, and some other forms of energy. In agriculture, it means making available green energy and being able to maintain electricity for farming activities. The review will focus on energy access/usage for boosting farming activities in rural communities of Sub-Saharan African nations. It will also offer a critical review of the methodical investigation by different researchers on photovoltaic solar energy and electrification in agricultural applications for quality improvement in energy generation in rural areas for agricultural purposes, which in turn generates employment opportunities for people living in rural communities in Sub-Saharan African countries. The investigation covers several forms of photovoltaic systems, such as solar energy for cooling storages, pumping water for irrigation activities, heating/cooling greenhouses and drying crops for rural communities in Sub-African. It describes different principal application forms of photovoltaic solar energy in agriculture, photovoltaic solar energy issues, the principle of operation of photovoltaic, its uses, problems, and opportunities. Furthermore, this study discusses the economic analysis and market related opportunities of photovoltaic systems. It has been shown beyond reasonable doubt that photovoltaic solar energy would be an appropriate option for electrification in agriculture, particularly in the distant typical remote environment. The review concludes that the prospects of the research will be economic development potential and employment creation opportunities in the Sub-Saharan African communities.

Keywords: photovoltaic; energy; agriculture; Sub-Saharan; electrification; renewable

1. Introduction

Sub-Saharan African (SSA) nations are agrarian countries where over 60% of people living in rural areas are into agricultural practices [1]. The agricultural sector therefore has a major impact on SSA social and economic activities because most of its imports are related to the agricultural sector [2]. The driver of agricultural growth is the energy employed primarily to pump the water required for the irrigation of agricultural fields. The energy sector directly influences the economic development of a nation [3]. At present, 85%–90% of the global main power supply relies on fuel

derived from prehistoric organisms (fossil fuel) [4], which has reduced capacity in storage. A steady increase in the cost of these fuels is the primary cause of the recession in the global economy. To this end, the SSA agricultural sector is severely affected by the energy crise. To address the decline of the economy and related challenges in the energy sector, the world is focusing on the efficiency use of renewable energy sources such as photovoltaic solar power, wind, geothermal, biomass, and hydro [5]. SSA has a photovoltaic solar energy opportunity estimated at about 10,000 GW while the sun shines throughout the economic year on the section of the global map [6,7]. However, the SSA, which has over 950 million inhabitants, is the world's poorest electricity region [7]. In excess of six hundred million human beings are without electricity, and over millions of citizens are linked to an undependable network which in no way satisfies their day-to-day power supply operation. The rate of access to electricity in most nations in this area is approximately 20%, almost two in three citizens do not have access to the most recent electrical power supply operations. The average yearly electrical energy usage in the SSA household area is 488 Kilowatt/hrs. Per capita: this equates to about 5% of US energy consumption. According to the International Energy Agency (IEA), the electrical energy needed in SSA will rise by nearly 35% from the year 2000 to the year 2012 to get to 352 terawatt hours (TWh), and it predicts the overall electrical energy needed in SSA to amplify at an average pace of 4% a year through 2040 [6–9].

Agricultural activities are germane to humans as they are the only source of food for them. But agricultural processes demand regular energy resources to operate machines, water pumps for irrigation purposes, supply electrical energy to rural farm houses, dry agricultural products, and for heating and refrigeration processes. All are exploited in a conventional manner, using fuel derived from prehistoric organisms. The use of fuel derived from prehistoric organisms on farms increases global warming by releasing numerous greenhouse gases. This prompted academicians, scientists, and researchers to look for a different and able-to-maintain agriculture practice using renewable energy sources like photovoltaic solar energy techniques to alleviate environmental enigmas that can lead to warming of the Earth's atmosphere issues and changes in global weather patterns [10].

There are numerous potential sources of sustainable forms of energy; nevertheless, photovoltaic solar energy is the most excellent since it can be installed in nearly all parts of the land surface the Earth, without being polluted, contamination free and with good cost effectiveness. This was followed by the work of numerous researchers, academicians, and scientists who are attempting to raise community awareness of the environmental issues caused by changes in global weather patterns and the increase in the world's temperature. Climate change is exacerbated by the use of fossil-powered machinery on farms, which emits large amounts of greenhouse gases. The utilization of photovoltaic solar power emits no greenhouse gas emissions, in contrast to fuel derived from prehistoric organisms. Consequently, numerous developing nations are shifting to easy to renew and sustainable energy sources like photovoltaic solar power, which can be utilized for a variety of purposes, such as crop production, agricultural practices, pumping of water for irrigation purposes, drying of agricultural products, heating of premises, means of supplying fresh air, and so forth, in order to minimize environmental issues. There are two ways to convert energy from

the sun into electrical power: the use of photovoltaic solar power systems and the employ of solar capture thermal techniques [11]. In a photovoltaic system, the beams of the sun are directly converted into electricity by solid state semi-conductors, which require additional investment. Lately, as a result of advancements in solar power technology, thermal techniques have also been utilized for electrical power. Nevertheless, the main emphasis of the journal paper will be to review the relevance of the photovoltaic solar power technology system because the power method of application of tools and methods has the primary aim of meeting the electrical energy demand in a reliable, accurate, efficient, and effective manner in the framework of industrial techniques, surroundings, and financial careful thought because it is the most excellent sustainable and renewable type of energy alternative for rural communities with unsteady and unstable power supplies [12–15]. Since about half of the global population lacks access to present-day power supplies and numerous human beings still depend solely on carbon containing fuel for energy, embracing this system is dependable, efficient, effective, cost effective, immaculate, affordable, and extremely reliable because it is not risky to health as well as the surroundings. For this reason, over the last few decades, there has been a steady increase in the use of photovoltaic solar energy systems on remote rural farms [16–20].

This paper intends to critically examine the materials with the following queries: How is photovoltaic solar energy technology being applied in agricultural farms for sustainable growth? How is the photovoltaic solar energy system used on a farm? What factors affect the effectiveness of photovoltaic solar energy? Principal application forms of photovoltaic solar energy in agriculture; photovoltaic solar energy issues; photovoltaic solar energy uses; difficulties and opportunities; solar PV's value and demerits; obstacles and challenges in the process of adopting solar photovoltaic (PV) in the agricultural sector; and future policy recommendations regarding the use of solar photovoltaic energy for rural agricultural activities in sub-Saharan African countries.

Figure 2 depicted the space scattering of sun radiation in Sub-Saharan Africa nations, emphasizing strong-potential regions of focused radiation emitted from the sun and solar power development.

Figures 1–3 illustrate SSA has a special worthy favorable condition to increase its energy production capability without SSA exacerbating change in global weather patterns as a result of its well-supplied/plentiful resources that can be sustained [21].

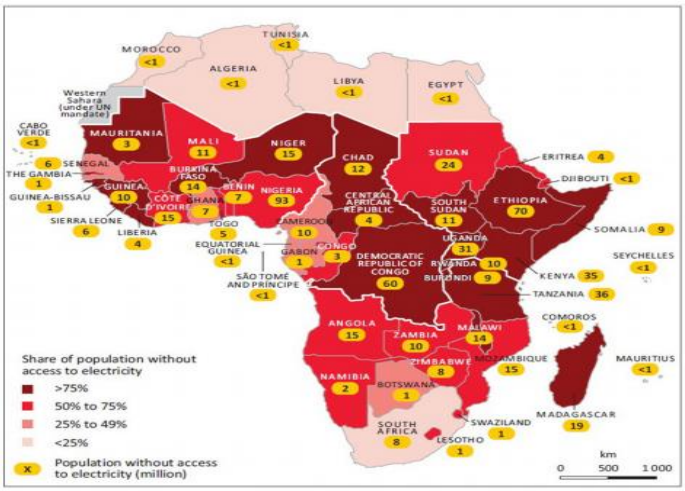

Figure 1. Electricity availability rate and overall people in a place without electricity access [1,22,23].

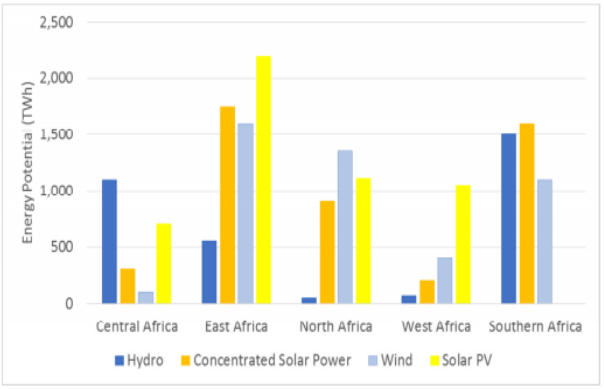

Figure 2. Large potential for renewables in Sub-Saharan Africa [1,23].

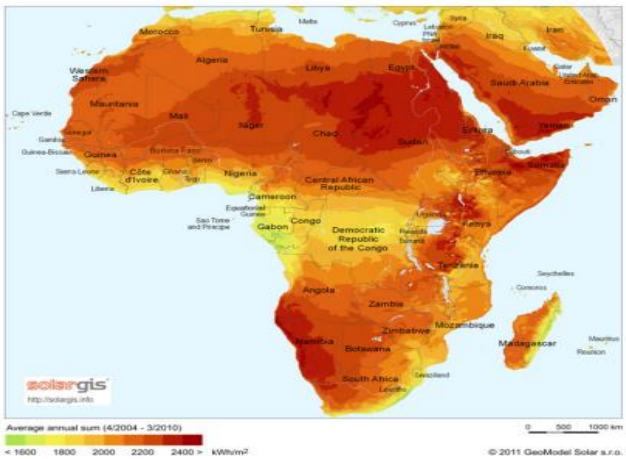

Figure 3. Sunlight radiation in Sub-Saharan African countries [22,23].

2. How is the photovoltaic solar energy system operated within the farm

The photovoltaic solar panel system provides low-cost green power, which is the best option for remote farms such as pumping water for crop irrigation [24]. However,

the functioning of the solar panel technology system requires the following: pump control mechanism, efficient source of sunlight, electric motor pump, photovoltaic solar power panel, water reservoir for water storage and means of water resource. There are several silicone cells or photovoltaic solar power cells in the photovoltaic solar energy panel. Photovoltaic solar cell is the smallest unit of the flat rectangular part. When the sunlight comes down on the solar panel, the vigor from the sunshine is absorbed by the photovoltaic energy solar cells. The photovoltaic solar power will be changed to unidirectional electrical current by partially conductive solid, then the control mechanism inserted in the inverter circuit will transform the unidirectional electrical charge to sinusoidal charge and the power will pass through to the electric motor pump control mechanism, subsequently, the electric motor pumped water and stored in the water reservoir [25]. As depicted in **Figure 4** the use of water for irrigation purposes for remote agricultural farming.

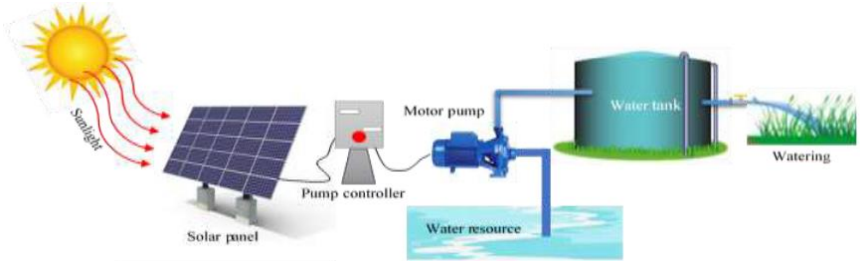

Figure 4. Operation of the photovoltaic solar energy system as an irrigation system [22].

3. What factors affect the effectiveness of photovoltaic solar energy

Various factors affect the effective functioning output of photovoltaic solar energy these include:

3.1. Shading

Shading is the term used when photovoltaic solar energy panel is covered with shadows, this usually produce enormous effect on the energy generated by the solar energy [14,26]. Mani and Pillai [27] stressed that the effect of dust on the photovoltaic solar energy panel can be affected by the characteristic quality of the dust and the immediate remote environment. Dupraz et al. [28] further stated that the distinctive feature of the dust contains; constituent element, dimension and quantity of matter, this may be in form acidic substance, which can cause the photovoltaic solar energy panel to corrode. According to Maghami et al. [26] and Maher et al. [29], which affirmed that the immediate remote surrounding means the surrounding where people daily activities like animal activities, salt, dropping from birds and irrigation systems and also state of atmosphere; rainfall, wind, snow, cloudiness and other meteorological conditions can lead to poor performance of photovoltaic solar power system.

3.2. Sunlight intensity

The electric charge of a photovoltaic solar power panel is directly proportional to the strength of photovoltaic energy emitted. Maghami et al. [26] and Maher et al. [29] stated that photovoltaic energy solar lighting effect and degree of heat cell have direct

effect the energy generated of the photovoltaic solar power panel. It has been observed that as degree of heat increases above the approved functioning temperature of 25 ℃, the photovoltaic solar energy panel functions less effectively and there will be total reduction in electric potential. Accordingly, degree of hotness can be judged as opposition to the free movement of elementary particle called electrons. Maghami et al. [26] and Maher et al. [29] observed that a photovoltaic solar power panel working at temperature 80–90 ℃ will losses 0.5% in effectiveness per every degree increase in degree of heat. In view of this, there is need to put in place a device to extra heat above and below the photovoltaic solar power panel.

3.3. Load resistance

This factor helps to ascertain the electric potential at which the photovoltaic solar power panel will function effectively and reliably. The effectiveness of the photovoltaic solar energy panel relies on the resistance of the load employed in the design. To ensure the operating electric potential and electric charge are properly matched with the load functioning requirements the control mechanism must be effective in tracking the greatest possible power needed. Furthermore, the voltage of the system can be increased; this will certainly reduce the loss in resistance of the system. By double the electric potential of the system this will decrease the electric potential drop by 25%. For the overall efficiency of the photovoltaic solar energy system, cable size and length must be carefully and painstakingly selected and given special consideration during planning phase [13,20,26–29].

3.4. Poor maintenance

Effective maintenance is the key to optimal performance of photovoltaic solar energy system. The existence of an unclean substance such as dust, soil and earth on the photovoltaic solar power solar panels vaguely decease the most desirable and favorable efficiency of the system. Photovoltaic solar energy modules frequent cleaning is hereby recommended [27–29].

Similarly, to these mentioned vital factors, there are other affecting factors influencing photovoltaic solar power optimal performance these include; Inverter efficiency, battery efficiency, mounting position of the PV solar power modules, charge controller and category of PV solar energy module employed.

4. Importance of renewable energy for the farm

Sunlight is an essential source of able to be renewed form of energy on Earth. Photovoltaic energy getting the Earth far exceeds the available yearly resources of other kinds of able to be renewed form of energy sources, as well as overall reserves of all fuel derived from prehistoric organisms [30]. The amount of photovoltaic solar power reaching Earth is calculated to exceed human energy requirements more than 5000 times [31]. An estimated of 0.02% of sunlight energy getting to the Earth is employed to generate power supply in photovoltaic solar energy plants in the entire world [32], this result in the present less effectiveness of the current application of tools and methods in resolving difficulties. Sunlight can be employed in photovoltaic solar power cells and photovoltaic solar collectors not only for photovoltaic solar

energy radiation, but also an energy source utilized in physical world occurrences which include movement of water in surface, processes of changing from liquid to vapor, motion in air mass, and processes of formation of rain, snow and hail [33–35]. The sun also provides energy for photosynthesis activities and processes [36–38].

Sub-Saharan African Nations are frequently confronted with the extremely bad power shortage as a result of huge power use for faster economic development, as well as severe environmental pollution from non-able to be renewed form of energy generation and consumption. The benefits of agricultural photovoltaic solar power applications are unparalleled and unmatched.

The following are the principal importance of Photovoltaic solar energy in sub-Saharan Africa nations, these include: enhancing the environmental quality, Reduction in conflict between more people and fewer lands, improved economic yields for farmers, and encouragement of the building of the modern socialist nation side.

4.1. Enhancing the environmental quality

Breyer et al. [39] stated that the agricultural system combines with a photovoltaic solar power system will decrease the emissions and enhance environment in an important way. Hence it is of great importance to develop a low carbon farming and green method of farming in Sub-Saharan African nations [40]. Breyer et al. [39] opined that to succeeding in combating change in global weather patterns photovoltaic solar power system is an important technology to employ. Liu [41] further stated that with a photovoltaic solar power system of electrical output three kilowatts will conserve coal of 35.2 tones, decrease dust by 60% tone, carbon (IV) oxide energy released of 91.4 tones, nitride of 35% tones, and S02 of 77% tones for the period of twenty five years of the system lifetime. In a similar way, Nacer et al. [42] stated that a 23 kWp photovoltaic solar power system can reduce GHG emissions of 544 tones over the entire life of the system.

4.2. Reduction in conflict between more people and fewer lands

Greenhouse photovoltaic solar power system farming production system mounded and placed over or on the top of the building of the farm greenhouse, may conserve land resources by not occupying the land and alters the nature of land use. With the increase in world population, this method of farming will perform an effective function in the arable land reduction. Dupraz et al. [27] and Weselek et al. [43] deduced that greenhouse photovoltaic solar power system maximizes the use of land.

4.3. Improved economic yields for farmers

To save the expenses of energy transmission as stated by Xinhuanet [44] the photovoltaic solar power system can be mounted on the top of the building or in any available free which can supply electrical energy for farming activities. Also the excess electrical energy generated from the photovoltaic solar power can be supplied back to support electrical network. Xinhuanet [44] opined that with just five kilowatts of power generated through the use of photovoltaic solar energy system linked to the electrical network, a farmer can make additional nine hundred dollars in a month as

economic return. In view of this, photovoltaic solar power system will significantly enhance the entire farmers live in the distant rural communities in accordance to the moderate's incomes from photovoltaic solar power system electrical energy production and farming products.

4.4. Encouragement of the building of modern socialist countryside

Xinhuanet [45] stated that to construct a modern socialist nation with successful and flourish financial economy, friendly agreement, facilities that are excellent, highly developed society and surrounding that are elegant in nature, which are unavoidable demands for the building of favorably placed community of people. The photovoltaic solar power system has been employed for building of remote area public service facilities, irrigation farming practices, treatment of waste water, supplying of electricity in remote area road, supply electricity to rural household, sewage disposal in remote area and lots more [46–48]. Seeing that photovoltaic solar power has energy saving benefits, security of the environment and conservation of energy, with the use of the photovoltaic solar power system is not only an effective solution to essential power use in remote, distant areas, except that, it likewise assist in the gradual improvement of the study of organisms and the environment and strongly promoting socialist highly developed society.

In a nutshell, it has immense significance and of very great value to adopt and advance photovoltaic solar energy agriculture in Sub-Saharan African Nations, because photovoltaic solar power agriculture will efficiently enhancing the environmental quality, greatly reduce the conflict between more people and fewer lands, clearly improved economic yields for farmers, and strongly encouragement of the building of modern socialist countryside.

5. Photovoltaic solar energy limitation; difficulties and opportunities

5.1. Photovoltaic solar energy limitations in SSA

Many authors have emphasized different kinds of limitations to installing and the employment of photovoltaic solar energy in Sub-Saharan African nations. In a similar way, photovoltaic solar energy manufactures and people that install solar energy in SSA are encountering the same challenges. The principal enigmas that discourage the deployment of PV solar power in the SSA are highlighted below [10,15,17,26,43,49,50]:

- Expensive of the photovoltaic solar energy parts.
- Non availability of money for the end users.
- Non availability of medium of exchange for manufacturers and people that install solar energy.
- Impression by the people that the cost of photovoltaic is high.
- Unresponsiveness of potential market groups: for example the real estate industry.
- Conscious creation; another limitation that has impeded the employment of photovoltaic solar energy in SSA. There must be improved awareness so that

people can know more of PV solar energy. End users request will intensify once the consciousness is increased and photovoltaic market will get larger and bigger. The over reliance on the conventional grid is the main reason for the PV lack of awareness.

- Policy of government on power and energy management: there are several limitations hindering the process of enlargement of photovoltaic solar energy utilization: The SSAN policy on money spent on the conventional power grid has been so high in comparison to the photovoltaic network being extended to the rural area communities is the principal reason for low coverage of photovoltaic solar energy when compare to other developed nations.

SSAN is blessed with sufficient deposit of natural renewable energy (RE) potentials ranging from solar, wind, hydro (small and large), biomass and fuel wood; RE has placed SSAN in a better position to advance her internal energy strategies. However, the nations are yet to integrate the vast RE potential into the energy mix. In addition, the mainstream energy supply chain is at present dependent on fossil fuels and firewood. These sources are grossly depleted due to the inability to harness other energy resources. The **Figure 5** shows the photovoltaic solar energy radiation potential in Nigeria.

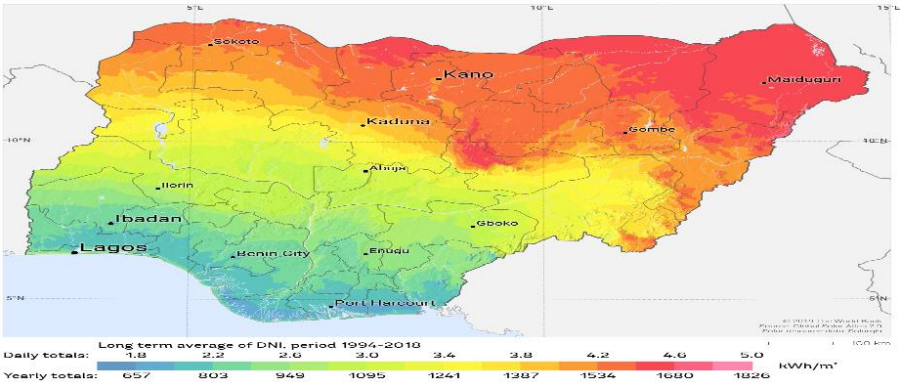

Figure 5. Photovoltaic solar energy radiation potential in Nigeria [1].

5.2. Limitations to photovoltaic solar energy utilization in Nigeria

This part listed the obstructions militating against photovoltaic solar energy in the federal republic of Nigeria, the most populous nation in Sub-Saharan African. Nigeria the giant of Africa is the most populated nation is the Sub-Saharan Africa with 6% of its population living in rural communities and the occupation of the people living in rural communities are predominately farming. Nigeria is situated in West Africa part of Africa, is the largest and significantly great nation among the countries in Sub-Saharan African nations with population over two hundred thousand people. Nigeria has photovoltaic solar energy radiation of average daily annual radiation varies from 12.6 MJ/m^2/day (3.2 kWh/m^2/day–25.2 MI/m^2/day 7.0 kWh/m^2/day). A series of obstructions hindering the process of enlargement of photovoltaic solar power in Nigeria include but not limited to [49,50]:

- Inconsistent and unpredictable of PV solar radiation: sunshine period in the Nigeria southern region and northern region respectively is calculated to be between 4 h to 9 h/day, because of this, the condition of solar energy being

available and accessible is not unreliable and incoherent.

- Network undependability: grid unreliability is a great enigma to PV solar power, as at present the grid in Nigeria functions between transmission voltage of 330 kV and 132 kV.
- Lack of awareness and information: the information about the development and benefit of PV are inadequate.
- Expensive starting capital price: high cost of starting cost is the most hindrances that prevent the full deployment of photovoltaic in Sub-Saharan African nations such Ghana, Nigeria, Zimbabwe, and there are no motivating factors to serve as encouragement on the importation of components and equipment of Photovoltaic solar energy tools for homemade industries in the nation.
- Control and continuing repair work is expensive: due to lack of technical know-how in the area of repair and continuous maintenance of PV solar equipment is extremely high. The federal Government of Nigeria policy on PV solar power and incentives to encourage or motivate people are enjoyed by conventional power sources while PV solar power source enjoy no subsidies of any form.
- Price simplification actions: deployment of photovoltaic solar power in Federal Republic of Nigeria is achievable. The resources to achieve this are not easily gotten. Banks and other organization offering financial services can make soft money lent available to the retailers at cheap price in order to design photovoltaic solar energy suitable for the people.
- Contest with land uses act subject of concern: land use act is a subject of concern is absolutely essential for photovoltaic solar energy project as the owners of the land are hindering the availability of their lands for feeling of anxiety of complete losing of the family legal inheritance.
- Coherent and logical cognizant awareness creation: photovoltaic solar power can be carried out effectively in a huge scale with reliable assistance and encouragement from the end users.

5.3. Barriers to solar energy usage in Sub-Saharan African

- Expensive and high cost of the photovoltaic solar energy components and parts.
- Non availability of capital for the customers.
- Non accessibility of medium of exchange for producers, manufacturers and retailers photovoltaic solar energy.
- Impression by end users that the cost of photovoltaic is extremely high.
- Unresponsiveness of potential market groups.
- Conscious creation.
- Policy of government on power and energy management.
- Unreliable and incoherent photovoltaic solar radiation.
- Undependability of the grid system.
- Lack of awareness and information.
- Expensive starting capital price.
- Control and continuing repair work is expensive.
- Price simplification actions.
- Contest with land uses act subject of concern.

- Coherent and logical cognizant awareness creation.

6. Principal application forms of photovoltaic solar energy in agriculture

Principal application of photovoltaic solar power system includes but not limited to the following:

- Electrification of warehouse;
- Controlling of risk;
- Direct current and alternating current water pumps (electric cell operated);
- Warming of Earth's atmosphere (lighting and windows automation); and
- Directly driven water pumps (no electric cell operated).

A photovoltaic solar power system in agriculture application has an unparalleled benefit of simplicity in installation, minimal maintenance and automation is absolute.

6.1. Employed for farm animals

Employed for farm animals [10,15,25,27,51–55]:

- Pumping of water to the farm animals;
- Use for cooling system for the preservation of milk;
- Electrification of farm and warehouse;
- Supply power for milking systems and
- Employ to supply power for fencing purposes to secure the animals.

6.2. Solar power controlling daily activities

Photovoltaic solar energy has enormous ability for PV solar energy irrigation system and can be employed to pump water for animals raised for food or other products, most especially farm animals such as meat and dairy cattle, pigs, poultry birds and food crops. We require to model and design or repair structures to trap the degree of hotness able to be gotten in daytime. The trapped temperature can also be employed to give degree of warmth in house residence and livestock house. Many livestock require an uninterrupted available amount of refreshing breeze. In order to keep away from outrageous electricity billing, a well-designed cooling system can be put in place. To achieve this well-designed building architecture of less expensive must be put in place through the house builder to effectively receive maximum sunlight. To supply hot water for the cleaning of cattle and cleaning of pen, photovoltaic solar power system is very useful. The use of hot water from photovoltaic solar power system to stimulate udders in cow and providing warmth in dairy services is commendable. The photovoltaic solar light can be employed to generate electrical power to supply electrical energy to farmhouses and remote rural community [56–64].

6.3. Photovoltaic solar power to desiccate farm grains and crops

A proportion of agricultural products in remote rural community are wasted when traditionally dried outdoors in Sub-Saharan African nations. Utilizing photovoltaic solar power techniques can desiccating the farm crops more quickly and at the same pace as leaving them exposed in the fields with the additional benefit of safeguarding them from farm animals such as; worms, rodents, insects, animals, and, birds. Spoiling

easily plants grown for food are frequently hard to desiccate and majority of the crops final get damaged, with photovoltaic solar power drying, one can desiccate the farm harvest crops and allows a means of storage period to take longer times and easier means of transport. The farm crops spoilage will drastically reduce greatly and this will help to increase the revenue generated for farmers [65–69].

6.4. Greenhouse heating effective usage

Warming of the earth's atmosphere known as greenhouses usually employ photovoltaic solar power to perform their recommended role. Except that it requires to be controlled with fuel and gasoline to keep at unchanging rise in degree of heat. Various techniques can be employed to magnify the effectiveness of the greenhouse except that the farmers generally prefer to use a heat sink [70,71].

The simplest and most preferred technique to control the degree of hotness in the greenhouse is to employ a temperature weight known as a heat dissipater. A heat sink refers to any substance that can take something up or in power and stores for use in the future. Water is a prime example. Photovoltaic solar power system temperature trapped in universal solvent can be employed for temperature regulation in the rural area of Sub-Saharan African nations [72,73].

Figure 6 depicts the photovoltaic solar power installed on the roof top. PV solar energy is a substitute source of energy which has the ability of producing heat and generating electricity. Of the group of all able to be gotten sources of energy produced by nature, light from the sun is the most, well supplied and abundant. Photovoltaic solar energy gotten from the sun is the world most plentiful and present in great quantities, cost effective source of power easy to get from nature. The quantity of photovoltaic solar power the surface of the Earth gets on a day with full of sunshine is enough of producing up to 200,000 times the overall daily power needed to supply energy to the entire world. The large amount of photovoltaic solar energy is only restricted by the collection techniques, means of storage and changing into degree of hotness and power. This, although, is gradually becoming things of the pass as a result of photovoltaic solar energy technology development and the cost of installing solar energy is decreasing day by day. The photovoltaic solar energy is free, clean, easy to maintain, dependable, reliable and self-renewable everyday all these make photovoltaic solar energy to be the best out of all figureable to be renewed energy sources presently available [72,74–81].

Figure 6. Solar panel on the roof top in Sub-Saharan African remote area [20,22].

6.5. The Earth receives an incredible supply of solar energy

The sun, an average star, is a fusion reactor that has been burning over 4 billion years. It provides enough energy in one minute to supply the world's energy needs for one year. In one day, it provides more energy than our current population would consume in twenty seven years. In fact, "the amount of solar radiation striking the earth over a three-day period is equivalent to the energy stored in all fossil energy sources."

There are several advantages of photovoltaic solar power that make it "one of the most promising renewable energy sources in the world." It is non-polluting, has no moving parts that could break down, requires little maintenance and no supervision, and has a life of twenty to thirty years with low running costs. It is especially unique because no large-scale installation is required. Remote areas can easily produce their own supply of electricity by constructing as small or as large of a system as needed. Solar power generators are simply distributed to homes, schools, farms rural areas for agricultural purposes [69–79,82–84].

7. Solar PV'S value and demerits; obstacles and challenges in the process of adopting solar photovoltaic (PV) in Sub-Saharan African Agricultural Sector

7.1. Merits

Solar photovoltaic farms are a simple way to generate safe, able to be renewed locally generated power for many years after construction. The most important benefits of solar photovoltaic agriculture are [71–75]:

- Low cost expenditure.
- The return of investment is in the future.
- It's able to be maintained.
- Keep one safe from increasing price of electricity.
- Photovoltaic solar power will increase revenue base.

Other benefits of using photovoltaic solar energy in agricultural sector in Sub-Saharan African include [76,85,86]:

- The lack of reliable electricity supply is a major concern for many rural farmers, many of whom have experienced severe losses.
- Much less when compared to fuel derived from prehistoric organisms: in very big farms, operating photovoltaic solar power will translate into a low cost than fuel derived from prehistoric organisms. It will be expensive to install, but immediately the amount invested is recovered, the energy utilization will be free of charge. Furthermore, subsidies from the central and state government will assist in the payment of the installation cost.
- An efficient answer to drought enigmas: yearly, farmers are concerned with the long period of dry weather and the resulting power outages. With photovoltaic solar power system put in place, agriculture's practitioner's reliance on third party to successfully carry out agricultural activities is minimal. The photovoltaic solar power system needs least possible water and it has been established to be of great benefit in the area faced with acute water shortage.

- Photovoltaic solar power storage for future utilization: most of agriculture practitioners at all times lives in anxiety of interruption in power supply, employing photovoltaic solar power system will be of help to many farmers. With the modern technology improvement to store photovoltaic solar power for future use is made easier. Agriculture practitioners can store photovoltaic solar power through the use of electric cells at peak period and utilize it in future time.
- The effective means of preventing climate change: climate change is the burning subject of the twenty-first century. Every sector of life is working hard to decrease its carbon dioxide and carbon monoxide releases to the atmosphere in one way to another. With agriculture practitioners employing photovoltaic solar power for their farming activities, it will be very easy to confront enigmas of climate change.
- Using solar energy technology such as photovoltaic solar panel in rural area agriculture in sub-Saharan African countries have many benefits: no cost for fuel, no noise and pollution of the environment, low cost of maintenance and the spare parts of solar panel are cheaper than using a generator operated by diesel engine, clean, abundant and available everywhere can be applied in many fields, including agriculture. Therefore, solar energy technology has become a solution for crop drying, greenhouse heating, water pump systems for crop production, livestock, electrification and small-scale irrigation [87]. This has been supported by Aroonsrimorakot and Laiphrakpam [88] who considered the economic and environmental factors related to solar panel adoption in agriculture. Similarly, Brudermann et al. [89] have shown the effectiveness of the fuzzy controller as well as the PV generator for saving the energy and lowering the costs of crop production into greenhouses. Therefore, application of solar panel application in agriculture can solve the problems associated with increasing population and less land while promoting the development of controlled environmental agriculture in order to increase economic benefits to farmers and also to improve the environment with the reduction of CO_2 emission into the atmosphere.

7.2. Obstacles and challenges

Besides enormous benefits for the photovoltaic solar power system, this technology presents challenges [86]:

- The initial expenses of installing a photovoltaic solar power system are too high mostly when it requires an enormous supply of electrical energy in large quantities.
- Solar PV has challenges regarding the uncertainty of how much of sun's rays it would receive, as weather can change from time to time. This would prove difficulty in determining how much energy to store for future use. Sunlight is clearly unavailable during night hours while there is still demand for electricity. In addition, peak radiation availability may not match with the demand for peak electricity. A mechanism for effective energy storage and efficient recovery is needed for this reason.
- Location can be an issue. The availability of solar radiation can vary depending on location. Some places, there are significantly more solar radiation than other

location. This would mean that solar energy generation is dependent on certain locations where the systems would need to be installed.

- The primary demerit regarding the employ of photovoltaic solar energy panel system is maintenance and cost of initial setting. As what was given in the report of world energy assessment, the present cost of PV electricity is high compared to the conventional power plants and this is a major barrier for large scale implementation of PV [29]. In addition, there are some problems associated with greenhouse cultivation as: Internal climate control, changing decision on the management of production and necessity to adapt the system to alternating metrological conditions [17,90,91].

8. Conclusion

This paper establishes the relevance and significance of photovoltaic solar energy as clean energy for sustainable growth in agricultural, especially in rural area of Sub-Saharan African nations. It is reveals that with photovoltaic solar energy in place, there will be dependable and reliable production and supply of agricultural good. Consequently, this will reduce urban migration and hence promotes social development. Finally, with adequate and proper maintenance of installed photovoltaic solar energy, youth unemployment will be totally reduced to acceptable minimal and this will definitely diminish poverty in rural areas of Sub-Saharan African countries.

Sub-Saharan African governments at all levels should promulgate laws and policy to support and stimulate the domestic growth of PV solar energy industry. For PV rural area agriculture, it has an unusually large potential for the local growth of photovoltaic solar energy in agriculture in rural communities of Sub-Saharan African as a result of effective and strong support policies, flourishing controlled environmental agriculture, policy-oriented rural electrification, promising electric machinery for greenhouse and continuous develop of PV technologies and products for agricultural production and farmers' life. It has very great significance to develop PV solar energy for rural agriculture in Sub-Saharan African, due to the fact that PV solar energy for rural agriculture can efficiently reduce to bearable minimum the contradiction between more population and less land, powerfully advance the CEA growth, evidently amplify economic advantages of farmers, and substantially add value to the environment.

9. Recommendations and suggestions

Policy recommendations for sustainable growth in rural area of Sub-Saharan African Agricultural Sector. There are many recommendations or suggestions to improve the efficiency of photovoltaic solar energy technology in rural area agricultural farming economically as well as environmentally [92–96].

Funding is critical to improving access to electricity in remote communities of Sub-Saharan African nations:

- Involvement of private sector is still the most significant choice for remote communities energy access.
- Investment of private sector is a critical step in securing power supplies for remote rural populations.

- Decision makers should give greater priority to the development of rural agriculture and supply of energy in remote areas.
- To ensure better planning and implementation supply of power to remote communities should be decentralized in order to keep rural populace at heart.
- The development of rural power supply has to be integrated into other facets of development in rural agriculture.
- To reduce the kWh-costs of PV, there should be improved in the cell and module conversion efficiency [55].
- Semi-transparent PVPs should be used and increased the light transmission to the crop [96].
- To improve long term system conversion efficiency, there is needed to use concentrator cells in sunny regions [27].
- To reduce the production costs of solar cells and modules, the amount of material for manufacture the cells should be reduced [13].
- To create shades on the cultivated land, it should have about 5 m elevated structure with solar panels along with the different solar panel design configurations so that the crops or plants cultivated on the underground surface can yield equally [97].
- A unified standard must be set up to standardize the design and scale of projects of solar panel or photovoltaic agriculture. Solar panel producers need to produce a variety of applicable PV products for agricultural production to meet farmers' requirements [98].
- Government designers need to make innovations with due consideration on the cost and efficiency in order to motivate farmers to use the alternative renewable energy generating device rather than using conventional fossil fuel energy for a pollution free environment [15,74].
- Need training of the farmers on how to use and maintain the PV system along with availability of a good support service [13,85,99–101].

Agricultural production is very important because its annual yields influence the security of food production in a nation. So, it is important to increase the output of production through the adaptation of technological innovations. However, there is a growing concern for environmental impacts due to the increasing usage of fossil fuel energy in agricultural operation processes, which generate lots of CO_2. As a result, all over the world, governments and industries, both public and private organizations, are increasingly finding a means to reduce the warming of Earth's atmosphere gas emissions from daily industrial and machinery operations by switching to green energy, that is, transitioning to sustainable, able-to-renew energy resources, for example, photovoltaic solar power. Solar panel farming is a better advantage for the agricultural industry as it helps accelerate the development of modern agriculture, even in rural areas. Due to the evolution of solar panel energy systems in agricultural technology, agricultural farm machinery, buildings, and production facilities are constantly being improved. This made solar panel agriculture a rapid development in developed countries due to government policies of innovative agricultural technology, resulting in rural farm electrification and machinery for greenhouses to maximize production while minimizing land use. However, more research and practical investigation must be conducted using innovative designs with less cost of installation,

while yielding higher output to optimize the combination of solar panel energy generation and agricultural cultivation in developing countries too. The article concludes that using PV panels in agricultural farming has more advantages than disadvantages, both environmentally and economically. The area of the Saharan desert photovoltaic solar energy government action plan is frequently explained as moving at snail speed. Regional weather plans, power supply initiatives, and energy-market reorganization and improvement frequently advance at an extremely slow speed. Except for not-long-ago introduction of free from pollution energy bidders, which opens a transparent and advantageous chance for manufacturers to find a means to penetrate the national able-to-renew energy market. In this area, the regional government action plan has been backed by DFI's sustained request for bids from sole buyer plan of actions.

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