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Solar Energy: A Potential Source of Energy for Agricultural and Rural Development in Ghana

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The current challenges of climate change and the fluctuating oil prices on the world market make it imperative to consider cheaper and alternative sources of energy for agricultural and rural development in Ghana. Solar energy is an environmentally friendly source of energy as compared to other conventional forms of energy and it is capable of providing all the energy needs of the world. This article seeks to draw the attention of government, NGOs, policy makers, stakeholders and the general public about the enormous energy from the sun and the need to tap such energy for agricultural and rural development. The research was carried out through field visitations and extensive review of important literature on renewable energy. The paper outlines the various uses of solar energy in agriculture such as crop drying and processing, pumping of water for irrigation, power supply, water heating and many more. It reviews solar energy use in Ghana and highlights the principles of solar energy. The paper also outlines the benefits and concludes with suggested recommendations which can help accelerate agricultural and rural development through solar energy application in Ghana.

Keywords: Solar energy; agriculture; rural development; photovoltaic; crop drying; crop processing; water pumping.

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1. INTRODUCTION

Solar energy is a reliable alternative source of energy for agricultural and rural development especially in Africa. Majority of rural dwellers in Ghana live in areas very far from the national grid and thus have no hope of being connected to the national grid. Besides, it is quite expensive extending electricity to the rural areas even though government of Ghana is working hard to extend electricity to the rural communities through the Self Help Electrification Project (SHEP). Most of the rural dwellers in Ghana, whose lives depend on agriculture, rely on kerosene, dry cells and other remote energy sources for light in their homes. According to De Groot [1] and Williams [2], majority of the people in the urban areas have access to electricity while only one third of the more than 2.5 billion people living in the rural areas have access to grid-based electricity. Frequent fuel increases and the threat of climate change make solar energy a viable option for sustainable development.

Solar electrification, however, offers an alternative to the expensive rural electrification programme, which is a mirage to most of these rural communities. As fuel prices keep swelling up, the solar electric equipment is gradually subsiding [3]. Solar energy technology has several uses such as water pumping for both community and irrigation, lighting in rural schools and institutions, health centres, provides streetlights, water heating, drying of crops and many more. It is environmental friendly, reliable and cheap in the long term.

The provision of solar energy in rural communities would bring about job creation, enhancement of rural life, curb the menace of rural-urban migration and improve the quality of life for rural dwellers. It is estimated that about 80 percent of the world's population live in rural areas of developing countries, most of them with no access to electricity [4]. This article therefore seeks to draw the attention of government, NGOs, policy makers, stakeholders and the general public about the enormous energy from the sun and the need to tap such energy for agricultural and rural development. It is important to note that solar energy uses no fuel, has low operational and maintenance cost and very cheap in the long term.

The reliance on hydro and oil and gas, as sources of energy production cannot be guaranteed due to possible drought and fluctuating oil prices. Currently, Ghana is facing energy crisis because of low levels of the Akosombo dam which is the major source of electricity supply in Ghana. The sources of energy, therefore, need to be diversified and those in the rural areas supported with solar energy for their development especially in Africa. Solar energy is clean and environmentally sustainable as compared to other forms of available energy. As a developing nation, energy is an indispensable commodity to help accelerate sustainable development, transform and expand the economy. However, the nation cannot depend on oil and gas as those resources are not renewable and their prices keep souring at an alarming rate. Goswami [5] has reported that current oil and gas reserves and the rates of consumption would only be sufficient to meet demand for the next 41 and 67 years respectively.

Renewable energy such as solar is therefore one of the best ways to provide sustainable development and arrest the challenges of climate change. Proper adaptation and application of renewable energy such as the sun will reduce the emission of CO_2 by 75% from 1985 levels by 2050 besides other numerous benefits such as crop drying, water supply, water heating and many more [6].

2. SOLAR ENERGY IN PERSPECTIVE

2.1 Basic Principle of Solar Energy

Solar energy is the radiation from the sun and can be transformed into three useful forms viz: chemical, thermal (heat) and electrical energy. Solar energy is converted into chemical energy in green plants through photosynthesis process. Photosynthesis is the synthesis of sugar from sunlight, CO_2 and water and gives out Oxygen as a by-product. Energy from the sun in the form of solar radiation supports almost all life on earth via photosynthesis and drives the earth's climate and weather [7]. Solar heating devices transform solar energy into heat (thermal energy) which is used for drying, water heating and cooking. For a solar heating system, the solar collector (commonly a flat plate collector) converts the solar irradiance into heat to warm water which is transported into an insulated storage tank or directly used. According to Norton [8] the amount of water produced using the solar heating system will depend mainly on the system size, location of the system, availability of the sun's energy, hot

water demand and the orientation of the system. The solar heating devices come in the form of passive or active solar designs. Passive solar design is very common for heating homes because they do not require additional devices such as pumps or fans unlike active solar designs. On the other hand, active solar system is suitable for solar water-heating where cold water is pumped through the collector pipes, get heated and transported into insulated storage tanks. Both passive and active solar designs can be used to improve the quality of agricultural products and increase their shelve lives.

Solar energy is also converted into electrical energy for powering radios, TV sets, refrigerators and many other devices. The sun's energy is said to virtually produce all the energy needs of the world. It produces about $3.8x10^{23}$ kW of power of which only 1.73×10^{16} kW reaches the earth [3]. The global capacity of photovoltaic installed was almost 2 GWP by close of 2002 and materials commonly used are silicon (Si) and compounds of cadmium sulphide (Cds), cuprous sulphide (Cu_2S), and gallium arsenide (GaAs) which are made up of various semiconductors [9]. The system can be used in conjunction with other energy sources in the form of grid connected system or as an independent device in the form of stand-alone system (7). The PV system is made up of the module, a charge controller to regulate the power from the PV modules to prevent the batteries from overcharging (batteries to store the energy produced when not in direct use), inverter to convert the direct current (DC) to an alternating current (AC) which is the normal energy form for many appliances (Fig. 1). Batteries are not needed when the energy generated is directly used in DC devices or fed into the national grid. The PV cells convert the sun energy to electricity through the process of photoelectric effect.

2.2 Solar Energy for Water Lifting and Pumping Systems

Water is very important in that it affects every aspect of our lives. Water is said to be one of the basic elements (energy, atmosphere, water, and soil) that affect the quality of life [10]. Water is needed for domestic, industrial and agricultural purposes. The need for water in irrigation is very pressing than never before due to population explosion and climate change. It is therefore not strange that water is used more in the agricultural sector than any other sector. It is estimated that about 70% of water consumption worldwide is in agriculture, 20% by industries and only 10% is for household needs (7). Available reports indicate that Egypt in 1996 had 100% of its productive land under irrigation, Pakistan and Japan had 81 and 63% respectively [11]. Israel is one of the countries with very good irrigation schemes globally. Unfortunately, in Ghana, only 0.2% (30,269 ha) of agricultural land is under irrigation even though the country has the capacity to put about 500,000 ha under irrigation [12]. Besides, several water bodies across the country have been polluted by illegal mining making accessibility to surface water for household and irrigation very difficult especially communities that rely on rivers and other water bodies [13]. According to Delyannis and Belessiotis [10] water pollution is becoming one of the greatest causes of freshwater shortages globally. Relying on underground water is therefore very important to ensure regular water supply for domestic and agricultural purposes.

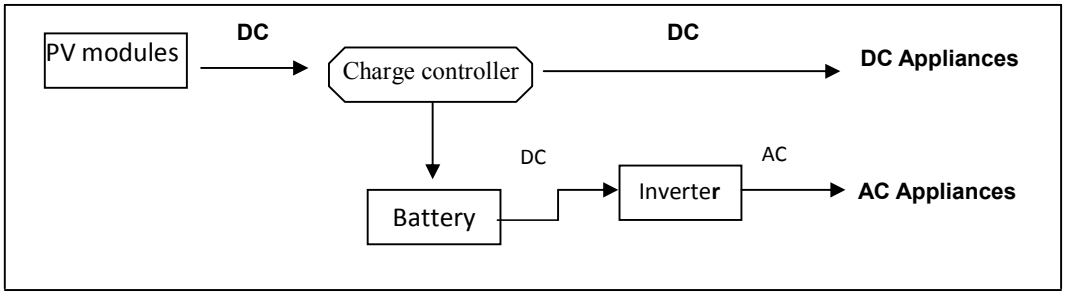

Fig. 1. Simple design of a PV system

The use of solar energy for water pumping and lifting has gain recognition worldwide as most countries use the technology in increasing agricultural yield. Solar energy can be utilized to operate solar pumps, which is used in drawing water from dams, boreholes and wells for irrigation and domestic consumption. Water is always pumped in sunny days and stored for use during cloudy periods. Durin and Margeta [14] in their paper have confirmed the possibility of using solar energy in solar generators to pump water for urban water supply. In view of the fluctuating weather patterns and high water demand for domestic and many irrigation schemes, solar energy needs to be stored in the form of either electricity in batteries or lifted water into storage tanks as indicated in Fig. 2. The importance of solar energy in agriculture, domestic water supply and irrigation cannot be overemphasized. However, the handling, operation, management and maintenance of the solar pumps could be a major challenge thus the need for adequate training of key personnel in the communities to maintain the facilities.

The suitability of solar energy for lifting water to irrigate crops cannot be overemphasized because the higher the intensity of the sun the more water is pumped for irrigation. This ensures an all year round food production by farmers, as water is not needed during rainy season. The tapping of underground water for irrigation will help farmers to farm all year round, prevent migration and ensure food security. Small-scale irrigation is among the most potential uses of solar energy. As government of Ghana has recognized agriculture as the key element for poverty reduction and sustainable development, the use of solar energy in agriculture will be a better option to improve agricultural development and create rural employment. Lack of familiarity and knowledge about the technology could be the main limitation to the use of solar energy apart from the financial constraint; however, such limitations could be removed with proper budgeting, planning and education. In an era of climate change, the use of groundwater for irrigation purposes will be more urgent than before. The application of solar energy to harvest water can help the continuous adaptation to climate change and reduce the global carbon footprint [15].

2.3 Solar Energy for Crop Drying

This is the use of sunlight to remove moisture from farm produce in order to prevent molding and facilitate the storage life. The energy is used in drying cash crops, fruits, fish and others as indicated in Fig. 3. The use of traditional method of drying has been there for centuries and it is still relevant in rural communities as discussed in Kalogirou [16]. Crops dried in the open sun are mainly exposed to dust, insects, and stones resulting in the low quality of the product. In the rural farming communities in Ghana, major crops especially grains are dried in the open sun. This method is even though cheap, it is labour intensive. However, the application of new and improved solar drying techniques will improve product's quality and market value.

2.3.1 Improved methods of sun drying

There are various forms of solar dryers. Among these are direct solar dryer where the sun's energy directly and continuously heat the material until it dries (Fig. 4a) and indirect solar dryer where the sun's energy is used to generate

Fig. 2. Solar water pumping for rural water supply and irrigation (Author)

hot air in one chamber and through convection moves through the crops to remove moisture in another chamber above (Fig. 4b). In both methods, solar radiation is trapped inside a transparent glass to heat the air, creating a hot environment to hold and carry water vapour. The warm air moves through the product, extracts moisture from the product and escapes through a vent or chimney while cold air comes in to replace the warm air inside. This process continues until the products dry up completely. The improved solar driers ensure quality of the product in that they prevent dust, micro-organisms and insects from affecting the products.

Fig. 3. Traditional sun drying in rural communities–goggle images

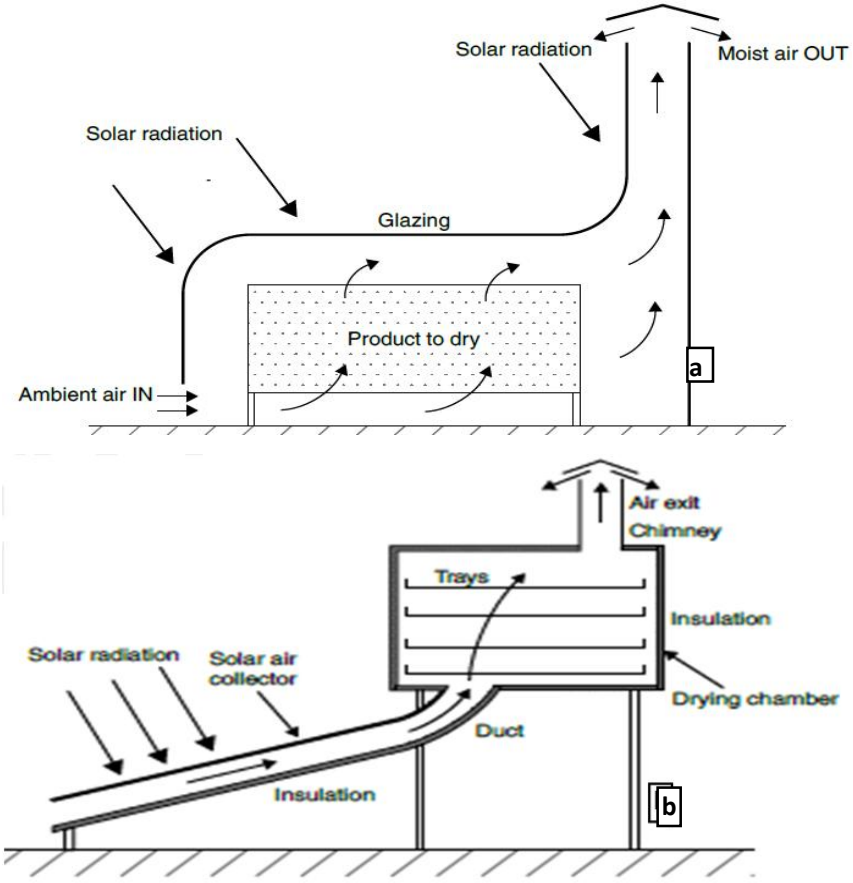

Fig. 4. Examples of Improved methods of solar dryers (7)

2.4 Solar Energy for Other Applications

2.4.1 The green house effect (GHE)

The principle of greenhouse effect is mainly used in research facilities to investigate plant growth and yield through the process of photosynthesis. Photosynthesis drives plants growth by using CO_2 in the atmosphere together with water, solar energy and mineral salts to produce carbohydrate releasing O_2 as a by-product. The green house is made up of transparent glass or material which allows solar radiation (short wave) to enter the glass or material. The energy is then absorbed by the materials in the greenhouse which is then converted into heat (long wave). A fraction of the heat escapes into the atmosphere while the rest remain inside the system. The heat inside the greenhouse causes the temperature to rise. Glass is almost transparent to short-waves but opaque to long-waves (infrared) radiations. The air trapped inside creates a new environment within the greenhouse for crop drying and growth. The GHGs are gases that absorb radiation from the sun and emit the energy back to the atmosphere in the form of infrared radiation. The process of absorbing and emitting radiation from the sun to regulate atmospheric temperature constitute the greenhouse effect.

The GHE is very important as it keeps the global temperature at an average of 15ºC without which the temperature would have been 34ºC lower [17]. The GHE has made it possible for the earth to be habitable but research has indicated that, there have been an increasing concentrations of GHGs especially CO_2 in the atmosphere and this increasing trend has been attributed to human activities such as burning of fossil fuels like coal, oil and gas, industrial emissions, deforestation, burning of vegetation, draining of wetlands, clearing of land for agricultural purposes among others [18]. The higher concentration of the GHGs especially CO_2 creates a thickening layer of pollution above the earth, trapping in heat which eventually causes global warming. Carbon dioxide is the most important GHG that is increasing in concentration in the atmosphere due to human activities and has contributed over 70% of the enhanced GHE until now with methane contributing about 24% [19]. The GHGs will have adverse effect on water resources, agriculture, health and the general ecosystem of the world [20]. The use of renewable resources is therefore one of the best ways to avert global catastrophe due to climate change.

2.4.2 Solar electricity

Solar energy is also used to power electrical gadgets, solar lamps and street lights. The solar energy is converted into electrical energy and stored in batteries or directly used. In rural areas far from the national grid, electrical energy is mainly used for street lightning and in health facilities. The energy is stored in batteries during the day and used to power a stand-alone system to provide light in the night. The solar arrays produce direct current (DC) which can be used directly in devices designed to use direct currents otherwise an inverter is used to convert the DC into an alternative current (AC) to be used in AC appliances. The energy generated can also be stored in batteries for a later use. In this case, a charge controller is fixed to regulate the energy delivered into the battery to ensure safety of the battery as indicated in Fig. 1 above. The electrical energy generated is stored in batteries and used to provide street lights, charge phones and solar lamps for rural communities. Solar energy application for electrical energy will improve social life in rural communities.

2.4.3 Solar water heater (SWH)

Solar water heater is one of the popular methods of solar energy application in many cities. It is normally made up of solar collector array, the piping system and a storage tank to store the hot water or used directly. The sun's energy heats the heating devices which in turn heat the water through the method of convection. Heating can either be done using passive (thermosiphoning) system or active (pumps) system. It is applicable in rural health facilities, small processing industries and for domestic applications especially where energy is unavailable.

2.4.4 Solar cookers

This is the method of using solar energy for cooking. This is done by concentrating the energy at a point and used for cooking various food items. Solar concentrators and reflectors redirect scattered solar radiation incident over a large area, focusing them into a small area where it is harvested at high temperatures for cooking and it comes in various forms such as parabolic dishes, parabolic troughs and simple reflectors.

3. OVERVIEW OF SOLAR ENERGY IN GHANA

3.1 Application of Solar Energy in Ghana

The idea of solar energy technology is not new in Ghana except that it has not gained much attention nationwide even though the climatic conditions favour such technology. It is mostly applied only within the telecommunications, rural health, streets lighting and water supplies installations (Table 1). However, it is quite unfortunate that such huge source of energy has not been well tapped for agricultural and rural development. According to Rats chow [21], farmers cannot operate successfully without access to energy. Ghana receives daily solar irradiation of about 4-6 kWh/m^2 with a corresponding long annual sunshine between 6-8 months especially in northern Ghana. Currently the government is focused on achieving10% generating capacity of electricity from renewable energy by 2020. This is evidenced by the various solar energy projects including the 155 megawatt Nzema project in the Western Region by Blue Energy (UK-based Renewable Energy Group). There are other World Bank, JICA and Government of Spain solar energy projects across the country. German government has also pledged to support the renewable energy sector in Ghana when the President of Ghana visited Germany on the 18th of January 2015. Some of the solar energy projects in Ghana are in operation while others are only for academic purposes. Examples are the thermosiphon solar water heater built at Kwame Nkrumah University of Science and Technology (K.N.U.S.T), Kumasi [22]. The Kalba district hospital which had no electricity as at 2008 was fully powered with solar energy. Besides, several communities in the three northern regions have been provided with solar lamps and solar streets lights. Some of the Community-Based Health Planning and Services (CHPS) compounds in the rural areas are connected to solar energy. Wa Polytechnic since 2008 has been involved in the designing and building of solar lamps for rural communities through the Socialite and Jicalite energy projects.

There are a lot of other solar energy facilities scattered across the country which lack coordination and policy approach for its development. However, the future of solar energy in Ghana seems bright due to various interventions such as the current Blue Energy project; Siginik Energy Ltd (a Canadian Company) in collaboration with the Electricity Corporation of Ghana is to install a 50MW ground mounted tracking solar in Ghana- the largest in West Africa. The VRA is also to construct a PV solar plant at Navrongo to generate electricity for the region. The recent workshop organized in Kumasi by the Solar Capacity Upgrading Project (Solar CUP), the International Institute for Water and Environmental Engineering (2iE) and the Energy Centre (TEC) of the College of Engineering at the Kwame Nkrumah University of Science and Technology was focused on the role of renewable energy especially solar energy technologies to meet the energy needs of the West Africa sub-region and many more.

All these measures are very important in ensuring sustainable development and promote renewable energy use in Ghana but requires political commitment and contribution from all stakeholders. However, attention should be given to agriculture which is the backbone of the economy. For government to realize food security in the country, energy for agricultural development in the area of land preparation, irrigation, and crop drying and crop processing should be a matter of concern.

3.2 Solar Energy in Agriculture

The need for energy in agriculture for higher productivity is very crucial especially in developing countries. In Ghana, as in most African countries, farmers always have problems processing their food crops due to lack of sufficient energy especially those at the rural areas. It is becoming increasingly difficult for most countries in Africa to meet the exponential demand for agricultural produce thus many people suffer malnutrition and hunger. Much of the food produced in the rural areas gets spoilt due to lack of energy to process the food crops coupled with poor and inaccessible roads to farming communities. According to Kalogirou [16] the first known practical application of solar energy was for drying food substances for preservation.

If rural development is to be achieved, energy inputs must be made available for farmers and their communities, and this will require special efforts from the government and policy makers to develop appropriate policies that will ensure equitability in the distribution of the national resources in terms of energy supply. Solar energy could be used in agriculture for drying of food crops, water lifting for livestock and

irrigation purposes, provision of light energy and powering of electrical appliances. According to Ghana's Poverty Reduction Strategy (GPRS II, 2006-2009) document, the country's economic growth and structural transformation is to be driven by the agricultural sector. The first goal of the Millennium Declaration is to eradicate extreme poverty and hunger by 2015. It is also estimated that about 70% of people living in developing countries are rural dwellers who depend on agriculture for their livelihood [23]. The agricultural sector is therefore capable of alleviating poverty and hunger in these rural areas. People must have access to adequate food both in quantity and quality to stay healthy and active. There cannot be true development when majority of the populace are living in abject poverty and hunger. Solar energy has the potential of ensuring rural prosperity through the provision of adequate food and employment for the rural poor.

Statistics shows that Ghana has a total of 13, 628, 179 hectares of arable land of which only 7, 846, 551 hectares is under cultivation [12]. This indicates that more land could still be cultivated if the necessary structures are put in place. The use of solar energy for lifting water for irrigation will help farmers to expand their farm and cultivate all year round. Crop water requirement is highest during the dry season when the sun is at its peak. Solar energy also works best in lifting water for irrigation during such periods. Solar energy for drying and processing of crops will improve the livelihood of farmers and bring about food security. Rural communities will also have access to good drinking water through the use of solar energy to pump water from underground.

3.3 Summary and the Way Forward

Many agricultural products such as grains, cereals, nuts, tubers as well as beverages such as tea, cocoa and coffee are dried and consumed across the globe. Drying is very important to improve the processing, quality and preservation of such food stuffs. Without drying, many crops will go waste and much energy will be required to preserve them in their fresh state and some of them may not even be possible for consumption. This therefore confirms the importance of the sun's energy for agricultural and rural development.

Solar energy is known to be very reliable as long as the sun shines, cost effective, needs no fuel, requires very low maintenance and is environmentally clean energy, easy to transport to other villages, easy to work on, not dangerous as compared to electricity from national grid and many more. These advantages of the solar technology make the use of solar in agriculture overrule the limitation of being expensive. Even though the initial capital investment is quite high, it easily pays off after a few years of operation and the module can last for over 20 years [3]. With the use of solar energy, farmers stand to gain much in terms of crop yield. They can save time and labour, increase productivity, cultivate all year round, prevent post-harvest losses and improve their livelihood and that of their families. It will reduce poverty, bring about rural prosperity and intend bridge the gap between the rich and the poor.

Table 1. Inventory of solar PV application in Ghana as at 2004

s/n	Solar systems	Installed capacity	Generation
		Kilowatt	Gigawatt-hour
1	Rural solar home systems	450	0.70-0.90
2	Urban solar home systems	20	0.05-0.06
3	Systems for schools	15	0.01-0.02
4	Systems for lighting health centres	6	0.01-0.10
5	Vaccine refrigeration	42	0.08-0.09
6	Solar water pumps	120	0.24-0.25
7	Telecommunication	100	0.10-0.20
8	Battery charging stations	10	0.01-0.02
9	Grid connected systems	60	0.10-0.12
10	Solar streetlights	30	0.04-0.06
Total		**853**	**1.34-1.82**

Adapted from energy commission (24)

Provision of solar energy will increase regional and national energy independence, create employment opportunities for the youth, promote rural electrification in areas far from the national grid and save Ghana huge foreign exchange. Climate change is now a big issue globally and Carbon Dioxide (CO_2) is known to be the key Green House Gas (GHG) which causes global warming and it's as a result of the combustion of fossil fuel and human activities [25]. Solar energy technologies therefore play an important role in the reduction of GHGs such as CO_2, reclaim degraded lands and improve water quality resources [26]. For Ghana to take advantage of the huge energy from the sun, it may require political commitment for government, NGOs and other stakeholders to support research and development in renewable energies especially solar energy, provide farmers with the needed equipment for crop drying and processing to improve on the quality and shelf-lives of their crops. There should be tax incentives, subsidies and tax holidays for organizations and companies who want to invest in renewable energies in addition to the strengthening of institutions responsible for renewable energy development in Ghana. This must be supported by the establishment of national renewable energy development policy to provide a framework and encourage the design, development and implementation of renewable technologies in the country.

4. CONCLUSION

The use of solar energy technology is very important as has been clearly spelt out in the text thus one cannot ignore its enormous benefits. Africa is endowed with a lot of solar energy and we need to tap such huge resource for the benefit of the rural poor. Farming activities are mainly centered in the rural areas and it is the source of livelihood for over 60% of the Ghanaian population. Farmers can hardly afford the conversional source of energy such as the use of fossil fuel or electricity for processing their farm produce. It is therefore paramount to consider the availability of the solar energy in agriculture to ensure food security and improve the lives of the rural poor. What the nation needs to do is to put resources together to tap from this huge energy source for our national development especially in the area of agriculture, water supply and rural development. As the nation thinks about food security and poverty reduction, the agricultural sector must be the major focus and all hands must be on deck to ensure that farmers have energy for their activities all year round.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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