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Solar panel energy technology for sustainable agriculture farming: A review

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Abstract Agriculture is very important to human beings because it is the sole provider of food for human. However, agricultural processes require constant energy resources for machineries operation, irrigation pumps, greenhouse heating. All of these are conventionally operated using fossil fuel. The use of fossil fuel in agricultural farms accelerates climate changes as it emits lots of greenhouse gases. This made scientists, researchers and academicians to find an alternative and sustainable agricultural farming using renewable energy such as solar panel energy technology to mitigate the environmental problems that may result to global warming and climate change. Furthermore, to solve the alarming fear of exhaustion of fossil fuel. The authors present this article by reviewing literatures from various available sources. The article concludes that there is the need to conduct more researches in order to optimize the combination of solar panel energy technology application and agricultural cultivation among the agricultural farmers due to its environmental as well as economic feasibility.

Keywords: Agricultural farm, Application of solar panel energy technology, Environmental

Introduction

Agriculture is the main source of food for human beings. However, agricultural farm needs a constant energy supply for operation of machineries, vehicles, irrigation pumps etc. which is conventionally, generated by fossil fuel. There is an increasing alarm that these fossil fuels will be exhausted soon due to increasing continuous demand for consumption. As a result, scientists, researchers and academicians are currently investigating the need to find an alternative renewable energy for sustainable agricultural farming, which can maximize crop productivity for maintaining economic stability while minimizing the environmental impacts (Chel and Kaushik, 2011). There are many possible sources of renewable energy but solar energy is the best form as it is possible to put up in almost all parts of the earth's land surface, pollution free and cost efficient. This has been accompanied with the works of many scientists and academicians, who are

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trying to bring public awareness about environmental problems due to global warming and climate change. Climate change is heightened by using machineries operated by fossil fuel energy in agricultural farms as it emits lots of greenhouse gases. The use of solar energy does not emit greenhouse gases unlike fossil fuel. As a result, now adays many developing countries are switching to renewable energy such as solar energy, which can be used for various purposes, including agriculture farm cultivation, greenhouse cultivation, water pump for irrigation, drying products, space heating, ventilation and so on in order to reduce the environmental problems.

There are two methods of converting solar energy into electrical energy: *solar panel (Photovoltaic, PV)* system and *solar capture heating systems* (Hoogwijk, 2004). In the PV system, the sun rays are converted directly to electricity by semiconductors, but needs more investments. Recently, due to advances in the field of solar energy technology, thermal methods are also being used for power supply. However, the current article will focus on the application of solar panel (Photovoltaic, PV) technology since this energy system technology has the main objective to satisfy the demand for electric power effectively, efficiently and reliably within technical, environmental and economic considerations, as it is the best renewable energy option for rural areas that have unstable electric power supply (Torshizi and Mighani, 2017). Since almost half of the world's population do not have access to modern energy supplies and many people still rely entirely on fossil fuels for energy, adopting this system is efficient, affordable and reliable, because it is not hazardous to health as well as the environment. Due to this, in the recent decades, the number of users of Solar Panel Energy Technology in the distant rural farm is gradually increasing (GNESD, 2004).

This article attempts to review documents with the following questions:

1. How solar panel technology are being used in agricultural farm for sustainable development?
2. How solar panel energy system is being operated in agricultural farm?
3. What are the factors that affect solar panel performance?
4. What are the advantages, disadvantages and future recommendations of using solar panel system for agricultural farming?

Importance of renewal energy for agricultural farm

Several review of literatures have highlighted the importance of combining renewable energy and agricultural farming. They have discussed the different types of solar energy technology applications for crop and grain drying, space and water heating, greenhouse heating, solar photovoltaic system and water pump for irrigation. (Chikaire *et al.*, 2010; Mekhilef *et al.*, 2013). They have

considered solar panel / photovoltaic (PV) system as the most suitable option in agricultural works especially in rural distant areas since the maintenance of solar panel system is cheap with no environmental impact and can be used for many purposes. This is further supported by Qoaider and Steinbrecht (2010) who investigated the economic feasibility of PV technology in providing the energy requirements for irrigation in remote farming communities in the rural arid regions with aims of helping the communities, thereby decreasing the high costs of generating electricity using diesel. This innovative energy technology system is a key for leading the region to sustainable development. It is technically designed, including calculation of the life cycle costs (LCC) of a PV system, which can supply the entire energy demand of the villages. This solar panel generator has the capacity to pump about 111,000 m^3 of lake water daily to irrigate 1,260 ha land plots and also to electrify the adjacent villages' households. The authors found the efficiency of solar panel system generator by comparing it with diesel generator and found that diesel generated electricity per unit costs 39 c€ kW h^{-1} while a unit of PV electricity costs only 13 c€ kW h^{-1}, which is significantly cheaper. Similarly, Bardi *et al.* (2013) examined the possibility of farmers switching from fossil fuels to renewable alternative energy, which may result to increase in the quality as well as quantity of food production in several types of agricultural farms. Along with this, it can supply power for operation of agricultural machineries including vehicles for transportation and for field work. Currently, only a few machine operators in the agricultural sectors are aware of the problems related to fossil fuel depletion and climate change. This is the root cause of the problem of climate change. Unless there is an attitude change among the farmers, the problem will worsen. So, it is advisable for agricultural farmers to use energy saving devices for growing crops and to maximize land by using PV system because it is economical, cost saving and can be used for multiple purposes (Dupraz *et al.*, 2011). Similarly, Santra *et al.* (2017) considered agri-voltaic system as the future energy source for food production as it has the different options for using the system even in hot arid weather condition.

How solar panel energy systems are applicable in agricultural farm?

PV energy offers the best solution for remote agriculture and there are numerous applications of solar panel technologies in agricultural farm due to innovations in agricultural technology (Eker, 2005; Schneider and Schindele, 2018) as given below:

- The water pump which supports irrigation of cultivated crops
- The mechanical powerwhich serves for farm products supplies, transportation, storage, waste water purification and disposal

- The space, shelter or breeding for livestock and greenhouse heating which showed in Figure 1.

Dupraz *et al.* (2011) discussed the best strategies to convert solar radiation into both energy and food by designing the light transmission system at the cultivated crop by an array of solar panels and used a crop model that can predict its productivity. It is also called photovolotaic agriculture or Agrophotovoltaic (APV) and is a natural response to supply the green and sustainable electricity for agriculture (Xue, 2017). This system was developed by raising the solar panels to 2 m above the ground in order to increase moderate shading of the crops (Weselek *et al.*, 2019).

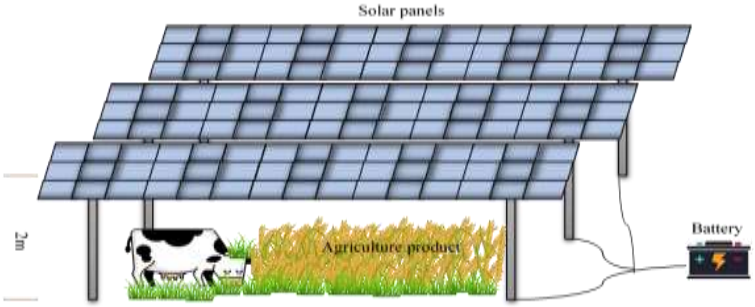

Figure 1. Solar panel technology system operation for both agriculture and livestock

Agricultural production is influenced by a number of factors such as climatic conditions, adequate water and energy supply. It is therefore important to optimize the agricultural productivity and maximize land use by application of new technologies with innovative farming strategies for economic efficiency and optimal use of scarce land resources with minimum impact on the environment. One such strategy is greenhouse farming system, where the indoor temperature and humidity conditions are controlled and determined for higher yield using solar PV energy as shown in Figure 2. The energy (DC power) from the solar panel is supplied to the battery. From the battery this DC supply is given to the inverter to convert it into AC power. The AC power is used to operate the ventilators in order to generate heat or control temperature in the greenhouse (Sharma and Samuel, 2014). Maher *et al.* (2016) also presented a model of greenhouse with a fuzzy-based control system to manage the indoor climate of the greenhouse using induction motors, heating system, and so on for ventilation, heating, humidifying, and dehumidifying purposes for a sustainable greenhouse crop production with effective climatic control for greater yield. Their study has shown the effectiveness of the fuzzy controller as well as the PV generator into greenhouses for saving the energy and lowering crop production cost.

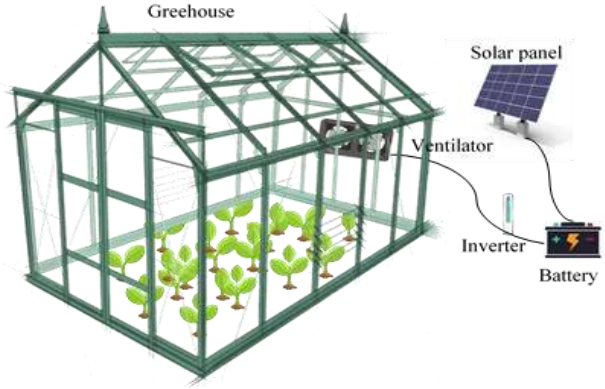

Figure 2. Solar panel energy system used as indoor ventilator to control temperature

How solar panel energy system is operated in agricultural farm?

Solar panel system offers green energy at a low cost, which is the best solution for remote agricultural farming operation such as water pumping for crops irrigation (Eker, 2005). However, operation of solar panel technology system needs the followings: adequate sunlight, solar panel, pump controller, motor pump, water resource and water tank. The solar panel contains several silicon cells or solar cells. Solar cell is the smallest unit of the panel. When the sunlight falls at the solar panel, the energy from the sun is absorbed by the solar cells. The solar energy will be converted into direct current electricity (DC) by semiconductors, then the inverter in pump controller will convert DC to AC or alternating current and the energy will flow to a motor pump, after that the water from water resource will be pumped by a motor and collected in the water tank (Conserve Energy Future, 2019). The water will be used for irrigation purposes in the rural agriculture farms as illustrated in Figure 3.

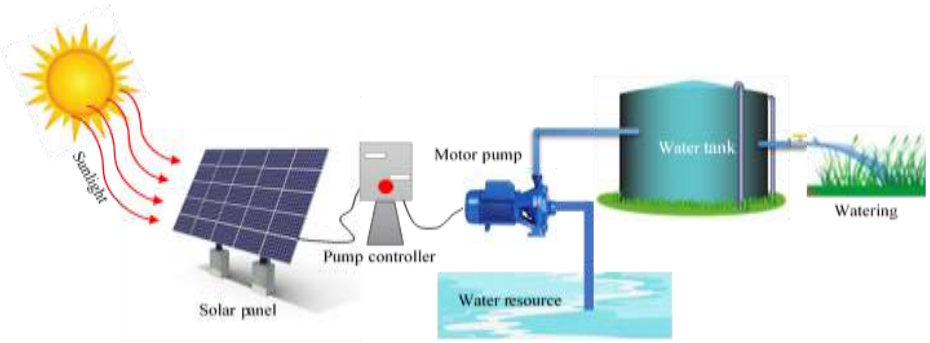

Figure 3. Solar panel technology system operation for irrigation purposes

What are the factors that affect solar panel performance?

There are many factors that affects the performance output of solar panels such as: *Load Resistance*: It determines the voltage at which the panel will operate. The efficiency of the panel depends on the load's resistance, so a control device that tracks the maximum power point must match the voltage and current operating requirements of the load. *Sunlight Intensity*: The current of a solar panel is proportional to the intensity of solar radiation. *Cell Temperature*: As the cell temperature rises above the standard operating temperature of 25˚C, the panel operates less efficiently and the voltage decreases. Therefore, heat can be considered as resistance to the flow of electrons. A panel at 80 - 90˚C, losses 0.5% in efficiency per every degree rise in temperature. So, airflow above and under the panel is essential to remove heat as installation of mounting scheme to remove heat. *Shading*: A slight shading of PV panels normally results in a dramatic output reduction (Wasfi, 2011). This is further supported by Maghami *et al.* (2016) who stated that factors such as solar irradiance and cell temperature influences the capacity of a solar panel system. In addition to these factors, there are other influencing factors affecting its performance such as reliability of other components and other environmental conditions. Among these factors, environmental factor is one of the top contributing factors which directly affect the solar panel performance such as the deposition of dust due to soil, salt, bird droppings, rainfall, snow etc. on the solar panel module surfaces as shown in Figure 4, or humidity impact due to irrigation for the crops resulting to inefficiency in the performance of such systems (Dupraz *et al.*, 2011). This dust effect on solar panels is further influenced by the dust property and the local environment. Dust property includes size, component, shape and weight. which can be acidic, causing erosion to the surface of the panel (Mani and Pillai, 2010). The local environment refers to the environment in which human activity has directly or indirectly created such as built environment, types of vegetation and weather conditions. All these factors can affect the solar panel performance technically by a reduction in power output, from 2-50% in different areas.

What are the advantages, disadvantages and future recommendations of using solar panel system in agricultural farm?

Advantages: Using solar energy technology such as solar panel water pumping system has many advantages: a) no cost for fuel b) no noise and pollution for the environment c) low cost in maintenance and the spare parts of solar panel are cheaper than using generator operated by diesel engine d) clean, abundant and available everyewhere e) 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

and small-scale irrigation (Aroonsrimorakot and Laiphrakpam, 2009). This has been supported by Brudermann *et al.* (2013) who considered the economic and environmental factors related to solar panel adoption in agriculture. Similarly, Maher *et al.* (2016) 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 environment by the reduction of CO_2 emission into the atmosphere.

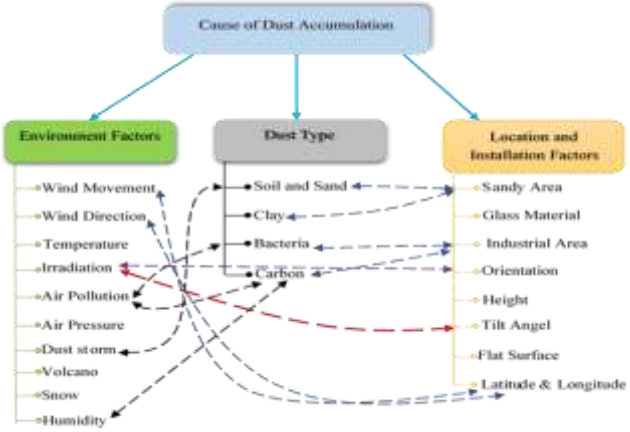

Figure 4. Cause of dust accumulating on the surface of solar arrays (Maghami *et al.*, 2016)

Disadvantages: The main disadvantage regarding the use of solar 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 (Goldemberg, 2000). In addition, there are some problems associated with greenhouse cultivation as: 1. Internal climate control 2. Changing decision on the management of production 3. Necessity to make the system adaptable to alternating weather conditions (Hatirli *et al.*, 2006; Heidari and Omid, 2011; Mohammadi and Omid, 2010).

Recommendations: There are many recommendations or suggestions to improve the efficiency of solar panel technology in agricultural farming economically as well as environmentally (Brudermann *et al.*, 2013; Dhamakale and Patil, 2011; Fabrizio, 2012; Esen and Yuksel, 2013; Mekhilef *et al.*, 2013). The following are the summarized the recommendation as follows:

- To reduce the kWh-costs of PV, there should be improved in the cell and module conversion efficiency (Green, 2000).
- Semi-transparent PVPs should be used and increased the light transmission to the crop (Dupraz *et al.*, 2011.
- To improve long term system conversion efficiency, there is needed to use concentrator cells in sunny regions (Turkenburg, 2000).
- To reduce the production costs of solar cells and modules, the amount of material for manufacture the cells should be reduced (Oliver and Jackson, 2000).
- 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 (Harinarayana and Vasa, 2014).
- 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 (Xue, 2017).
- 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 (Mekhilef *et al.*, 2013).
- Need training of the farmers on how to use and maintain the PV system along with availability of a good support service (Mala *et al.*, 2009).

Agricultural production is very important because its annual yields influence the food security of a country. So, it is important to increase the output of production through adaptation of techonological innovations. However, there is a growing concern for environmental impacts due to increasing usage of fossil fuels 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 looking for ways to reduce the greenhouse gas emissions from daily industrial and machinery operations by switching to green energy, that is, transition to sustainable renewable energy resources such as solar energy. Solar panel agriculture provides new opportunity for agricultural industry as it helps to accelerate the development of modern agriculture even in rural areas. Due to the evolution of solar panel energy system in agricultural technology, agricultural farm machinery, building and production facilities are constantly being improved. This made solar panel agriculture to have a rapid development in developed countries due to government policies of an innovative agricultural technology, resulting to rural farm electrification and machinery for greenhouse

to maximize production while minimizing land use. However, more researches and practical investigation must be conducted using innovative design with less cost in 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 as well as economically.

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