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2025 Volume 3, Issue 6
Lecture Notes in Education, Arts, Management and Social Science
ISSN(Online): 2705-053X

Solar Energy Applications in Agriculture

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Abstract: This essay is about to discuss several applications of solar energy in agriculture, including greenhouses, agrivoltaics. The demand for energy in agriculture is increasing day by day, but traditional power generation and fossil fuels are not only costly but also cause a large amount of pollution. Solar energy with its clean and renewable characteristics, has significant potential for improvement in the agricultural sector. By finding real case studies and research, readers can see how solar energy can help agriculture save energy, reduce emissions, and improve farmers' incomes. The article will also suggest future directions and recommendations.

Keywords: solar energy; agriculture; greenhouses; agrivoltaics

Online publication: July 26, 2025

1. Introduction

The energy problem is nothing new in the sphere of agriculture. There are many connections in agricultural production that entirely depend on energy forces. For example, irrigation and greenhouse heating systems and grain drying processes. Today's society is developing with great speed and people's need for energy is becoming very high indeed. Nevertheless, the main feature of the present economy is its reliance on traditional energy carriers, especially fossil fuels like diesel or coal. However, it will not only has significant expenses but also with increased volumes of greenhouse gas emission, which negatively affect the state of the environment. Researching the 2003 disaster in the US shows that this case caused over $10 billion in losses in the agricultural sector and claimed the lives of 20,000 people[1]. In numerous places, the agricultural branch consumes large volumes of energy, and the big part belongs to the non-renewable subgroup. Such energy structure is not only undermined but also creates more questions on the sustainability of agricultural production. Clean and renewable solar energy has become a very versatile source due to its superior benefits. This is an evenly distributed energy resource that is most accessible and cost-effective to operate in the countryside. It is more convenient for farmers. Therefore, using of solar energy in agriculture is not only a way to substitute fossil energy, but also an opportunity for farmers to lower the energy costs and make their business more profitable.

There are various forms of solar energy applications in agriculture, including photovoltaic power generation, solar water heating, greenhouse heating, solar drying equipment and agrivoltaic systems. Among them, agrivoltaics is a new model that combines solar power generation systems with agricultural production, and has been used in many countries. According to the data, there are 600 agrivoltaic sites in the US, with a cumulative installed capacity of more than 10 GW[2]. By installing solar panels on top of farmland, farmers can obtain additional power generation revenue without reducing the

area under cultivation, and the solar panels also provide partial shading, reduce evaporation, and improve crop yield and quality[3].

There are many people affected by this topic. The most immediate are the farmers who farm the land, especially those who are small and medium sized. They use a lot of electricity, which is costly, and if they can use solar energy, they can save a lot of money. There are also many remote rural areas where the power grid is unstable or even non existent, and with solar power they can generate their own electricity, making life and farming easier. In addition to farmers, governments, solar companies, universities and research institutes are also involved in this topic. Governments are responsible for issuing policies to promote solar energy and get more people to want to use it. Companies can be responsible for installing and maintaining the equipment, and universities and researchers can be responsible for refining the technology, conducting experiments, and helping people find better ways to use it.

So with everyone looking for cleaner, less expensive energy now, using solar energy in agriculture is not just a technological advancement, it can also help rural development. This is a joint effort between energy, the environment, agriculture and society on many fronts. A serious study of this issue will not only help farmers save energy and increase their income, but will also be of great help to the government's future policies, the promotion of solar energy products, and the modernization of agriculture.

2. Concept and applications of solar energy in agriculture

2.1. Concept

Solar energy utilizes sunlight to generate electricity or heat for various stages of agricultural production, such as greenhouse heating, irrigation, lighting, and drying. It is not only an alternative to fossil fuels, but also an important means of helping farmers reduce energy costs and improve economic efficiency.

2.2. Applications

The use of solar energy in agriculture has grown and is no longer a dream of the future, but a reality that is happening now. From greenhouse cultivation and pasture management to on farm power generation, solar energy is changing the energy mix and production methods of agriculture. This section will introduce the two main types of solar agriculture: solar greenhouses and agrivoltaics. Qne is to let the greenhouse run on solar energy, and the other is to build the photovoltaic panels directly on the farmland or pasture, realizing the power generation while planting. This approach is rapidly spreading in the U.S., Europe and other places. For example, the U.S. has hundreds of such large-scale projects in operation, and some projects can also bring additional ecological benefits, such as promoting pollination, soil improvement.

3. Methods

The research method in this article also has been mainly designed to take literature review as well as case study. First, in the literature review part, several academic works on solar agriculture usage have been cited, which were written by scholars and researchers, and reports as well as information published by organizations such as the U.S. Department of Energy, the National Renewable Energy Laboratory, and Enel North America. These sources serve to explain the state-of-the-art in solar technology implementation in agriculture, economic merit appraisals, environmental impact assessments, and policy support strategies[4-6].

Next, two representative application models were picked up for discussion, the first is solar greenhouses. This literature will consider their method of energy supply, energy savings, and their influence on agriculture production. The second is agrivoltaics, which identifies the photovoltaic panel design layouts, synergy effects between power generation

and food production, and improvement of ecological indicators such as soil quality and biodiversity. The case studies rely on large-scale demonstration projects and related research pilot programs across different US states, each with its own unique mix of scale, climate conditions, and crop types, providing lessons that can be useful for implementation in most regions.

4. Results

4.1. Solar greenhouses

Let's first examine the adoption of solar energy in greenhouse operations. Agricultural greenhouses typically demand energy for heating, lighting, and ventilation, particularly during the winter months or in colder regions. The reliance on conventional electricity or fuel optimized approaches to sustain the greenhouse environment incurs expenses and contributes substantial carbon emissions. According to the research conducted by Hassanien et al., solar energy plays a crucial role in facilitating various greenhouse operations or processes, including photovoltaic energy supply, heating via solar thermal collectors, and automation technology. Their findings indicate that installing a solar photovoltaic system for a greenhouse fulfills all electricity requirements for lighting and ventilation during the day and at night, eliminating the dependency on the conventional electricity grid. Furthermore, it has been reported that, in some greenhouses, the use of special translucent photovoltaic panels does not affect plant lighting, thereby serving to generate electricity and provide light at the same time. They found that residential energy consumption in greenhouses can be reduced by at least 30-50% through solar energy utilization, which means that farmers can save costs by relying on renewable energy while reducing carbon emissions and being environmentally friendly[7].

4.2. Agrivoltaics

Alongside greenhouses, agrivoltaics is a new model for combining agriculture and energy that is developing very quickly. This technique provides one plot of land with the two outputs. Additionally, it enhances the soil temperature and minimizes water evaporation, both of which are beneficial for the crops. Not just governments, but energy enterprises are also the ones who have such programs. To illustrate, Enel North America is a company that has developed several agrivoltaic projects in Texas and other parts of the US and is working with the local farmers and control vegetation on solar farms.

This project employs the field as an Eco-grazing farm, where more than 6,000 sheep and native plants are planted under the PV panels, while the field is under the PV panels. This practice, which is not only inexpensive regarding weeding and management but also conserves the soil and promotes biodiversity. According to official Enel data, such projects can increase organic matter in the soil by 200%, while the number of pollinating insects such as bees has increased by 20 times, helping pollination and yields of surrounding crops[8-9].

5. Discussion

There are three main forces driving these changes. The first is policy support. The U.S. Department of Energy's Solar Energy Technologies Office has provided quite a bit of pilot funding to support farms in establishing agrivoltaic projects, as well as providing guidance and research support[10]. The second is technological advances. The price of PV panels is now much lower than before, while the efficiency of power generation is getting higher. There are also many new technologies that are suitable for agricultural scenarios, such as dual-face panels, automatic light-tracking mounts, and semi-transparent panels, all of which allow for more flexible choices and higher efficiency. The third is market demand. The problems of electricity becoming expensive, unstable climate and energy insecurity have made more farmers pay attention to energy and stable income, and solar energy just meets these needs[10].

However, there are some difficulties in the development of solar agriculture. High upfront costs. Building photovoltaic

systems, the purchase of racking and distribution equipment, etc., all need a lot of money, small farmers without subsidies is difficult to afford. Another problem is the lack of uniform standards. Some of the PV systems built in different places are well designed, while others have too much shading and affect crop growth. In addition, there are some farmers who do not understand the new technology and are afraid to try it, or are concerned about maintenance difficulties. In order to cope with these problems, people are trying to develop standards for agrivoltaic projects, which will help the projects to be constructed and managed in a more standardized way[10-12].

In general, solar greenhouses and agrivoltaics systems have both shown practical efficiency and proven effectiveness. Looking at the situation from a view of saving energy, they can decrease the energy consumption by more than 30%, from the angle of income, they have a strong potential for improving the returns of farmers, and from the perspective of ecology, they can help to protect soil, water sources, and biodiversity. With the support of policy, technology, and the market, solar agriculture nowadays is coming into being as an important agent in ecological conservation and farm modernization.

6. Future actions needed

Although more farmers and businesses are now trying to use solar energy in agriculture, there are still quite a few practical problems to be solved before this technology can really spread and be used by more people. In the next five years, we can start from several aspects to promote the better development of solar agriculture.

First, the most difficulty is that it is too expensive. Although the price of solar energy equipment is much cheaper than many years ago, it is still too much money for many small farmers to build a solar greenhouse, or to build photovoltaic panels on their farmland. Many people even if they think solar energy is quite good, will give up because they don't have the money. In order to alleviate this pressure, we can promote the "share" approach. For example, a few neighboring farmers can build a small solar power plant together, use the electricity together, and share the profits, so that the burden on each individual is much smaller.

The next thing to be addressed is design. Now, a lot of places to use agricultural photovoltaic complementary, but the use of some different, some projects do well, some but the crops blocked the light, is because there is no uniform standard. Different crops need different light, photovoltaic panels frame how high, how much spacing, how to adjust the angle, all have to pay attention to. Therefore, we need to launch a set of agricultural design manual in the future, which clearly lists different crops, different climates, how to build photovoltaic systems. This set of standards could be developed by agricultural experts, solar companies, and governments so that everyone can use them.

Overall, this is a very promising direction, we just need to pave the way a little more steadily, so that more people will use it and be willing to use it. At that time, solar agriculture can really become an important force in rural energy transformation.

7. Conclusion

Overall, this study hopes to provide not just technical information, but an idea that can be grounded and implemented. Making agriculture more energy efficient and profitable through solar energy is indeed a development direction that deserves serious promotion. As long as policy, technology and farmers work well together, solar agriculture will play an increasingly critical role in the near future[13].

Disclosure statement

The author declares no conflict of interest.

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