

# Current Status and Future Development Trend of Solar Photovoltaic Power Generation

Yufan Yang \*

Shengli No.1 Middle School, Dongying, Shandong, 257000, China

\* Corresponding author: Jhawks52836@student.napavalley.edu

**Abstract.** Energy is the cornerstone of modern society's existence and development. In the face of increasingly scarce fossil fuels, the widespread adoption of renewable energy has become a crucial aspect of every country's future energy strategy. Solar energy is one of the many renewable energy sources that has attracted a lot of interest. This paper presents the current status of solar photovoltaic (PV) power generation, delving into its advantages and limitations. Solar PV systems convert light energy into electricity through light-absorbing materials, with the key component being the solar cell. While solar photovoltaic power generation boasts abundant reserves and minimal pollution, it faces challenges related to efficiency and stability. This paper aims to explore the benefits and drawbacks of solar PV power generation and propose ways to enhance solar cell performance for societal development and energy alleviation.

**Keywords:** New energy, solar photovoltaic, solar cells, silicon material, energy crisis.

## 1. Introduction

Energy is the cornerstone of the existence and development of modern society. According to the primary energy sources employed during various historical eras, the development of human energy can be loosely split into three stages: the era of firewood energy, the era of chemical energy, and the era of multiple energy sources. Since the Industrial Revolution, mankind began to step into the chemical energy era, with coal, oil and other non-renewable fossil fuels as the main sources of energy, increasing industrial productivity to a great extent. With the continuous development of the global economy and society, energy consumption has also continued to grow accordingly. Just as then, the problem of the fossil fuel scarcity arose and has been more and more critical ever since. Large-scale production and exploitation of renewable energy has evolved into a crucial component of all nations' future energy strategies in light of the increasingly strained supply of fossil fuels. Thus, researchers and scientists turned to solar energy which is relatively new to the world of energy. As a renewable resource, solar energy has many advantages such as lower pollution and greater efficiency. This is of much significance to alleviate the status quo of energy tension and environmental protection. However, due to the limitations of today's technology, the practical application of solar photovoltaic power generation is a complicated issue.

According to records, human beings have been utilizing solar energy for more than 3,000 years. But the utilization of solar energy as a kind of energy and power existed since only about 300 years ago. In the present, the main way for human beings to utilize solar energy is solar photovoltaic power generation [1]. With the increasingly serious energy crisis and the current development of science and technology, many countries have begun to try to turn to solar energy resources as the main source of energy in their energy strategies. For instance, industrialized nations like the United States and Japan have passed suitable laws to protect the rights of families that generate solar power and to entice households to do the same. China also promotes solar power generation through the development of emerging technologies and customization of relevant policies. In 2021, the State Grid Corporation issued the "Opinions on Doing a Good Job in Distributed Photovoltaic Power Generation and Grid Connection Services", which significantly reduces the threshold of PV power generation into the grid and encourages the market to enter the solar industry, which will help China's solar photovoltaic power generation industry to develop in a fast and healthy way.

The main purpose of this report is to analyze what benefits solar photovoltaic power generation can bring to the development of human society under the current situation of energy shortage, and what hazards are associated with its use. This paper explains why solar photovoltaic power production is a type of clean energy by first providing a quick introduction to the principle of solar photovoltaic power generation and the utilization of raw materials. Secondly, it focuses on analyzing the advantages of solar power generation over traditional energy sources, followed by an analysis of the problems that still exist in solar power generation. Due to technical limitations, this energy source is still characterized by instability and low utilization rates. Finally, combining the advantages and disadvantages of the previous section, certain suggestions are made for the future development of solar power.

## **2. Solar Photovoltaics**

### **2.1. Principle**

Utilizing water or other materials and tools, solar power generation captures solar radiation and converts it into electricity. Solar thermal power generation and solar photovoltaic power generation are the two main ways to produce solar energy. Without the use of thermal processes, solar photovoltaic power generation turns light energy directly into electricity. It encompasses various subtypes, including photovoltaic, photochemical, photo-induction, and photobiological power generation, with photovoltaic power generation systems being the prevailing choice. These systems are made up of vital parts like solar cells, batteries, controllers, and inverters, with solar cells being one of the most important. Solar cells facilitate the generation of charge carriers (electrons) within light-absorbing materials and separate these carriers to transmit electrical energy—a phenomenon known as the photovoltaic effect.

### **2.2. Material Utilization**

Since solar cells are an essential component of the photovoltaic power generation system, they have been produced and used since very early on. Silicon is a good material for the semiconductor and is abundant in our world: the second greatest element on earth: it also has the advantages of being stable and non-toxic. As a result, silicon has replaced other materials as the primary one used in the development, manufacturing, and use of solar cells [2-4]. Solar cells have gone through three stages of development, and are now mainly classified into two categories: crystalline silicon cells and thin film cells. Polycrystalline and monocrystalline silicon solar cells make up the first generation of solar cells [5]. Polycrystalline silicon cells are cheaper with similar efficiency relative to monocrystalline silicon. A 40  $\mu\text{m}$ -thick silicon can absorb 80% of sunlight, compared with monocrystalline silicon cells which need to be at least 200  $\mu\text{m}$ -thick silicon wafers to achieve the same effect. This is a substantial reduction in the consumption of silicon raw materials, so polycrystalline silicon batteries have occupied most of the photovoltaic market share. Thin-film solar cells, as the second generation of cells, are based on thin-film technology on top of a bondable film at the core. The advantage of this thin film is that it can reduce raw materials, be mass produced, and uses solar energy better [5].

### **2.3. Markets and Applications**

The market for solar PV power generation has started to grow quickly thanks to the establishment of regulations and ongoing technological advancements. According to EPIA's 2011 statistics, the cumulative installed capacity of PV worldwide from 2001 to 2010 continued to maintain an upward trend. Germany was the first country in the world to introduce a feed-in tariff law, and its PV market is booming, with PV installations accounting for a cumulative 13% of its electricity supply, and the cumulative number of PV installations is far ahead of other countries [6]. The world's photovoltaic energy production is currently moving toward grid-connected power generation in conjunction with building-based power supply. Taking China as an example, in the early 1990s, the main application areas of PV power generation were in communication and industry, including satellite communication

ground, program-controlled telephone exchange machines and so on. Since 1995, the use of domestic PV power supply systems has been encouraged, and large-scale PV power generation systems have steadily been built, mostly for power delivery in rural areas of China and specific fields. 2000, China's photovoltaic technology has entered into large-scale grid-connected power generation systems [7].

### **3. Advantages**

#### **3.1. Clean**

Traditional fossil energy sources produce gases such as CO<sub>2</sub> and methane during combustion, and since the actual CO<sub>2</sub> emissions have exceeded the rate of absorption of CO<sub>2</sub> fixed by nature, the earth will turn into a greenhouse, which leads to global warming [8]. Since 1995, the use of domestic PV power supply systems has been encouraged, and large-scale PV power generation systems have steadily been built, mostly for power delivery in rural areas of China and specific fields.

#### **3.2. Low Regional Restrictions**

Solar energy is available almost everywhere. In contrast, traditional fossil energy sources are not evenly distributed around the world. In order to ensure the stability of social development, fossil energy is usually transported from energy-rich regions to other regions where it is needed. However, energy is lost during transportation, and the construction of transportation routes incurs additional costs. The use of solar photovoltaic energy can lessen the need for the building of long-distance power networks and power losses on transmission lines, making it particularly ideal for rural locations without electricity. At the same time, solar photovoltaic power generation is also difficult to be affected by the energy crisis and fuel market instability, and can provide a relatively stable energy source for society.

#### **3.3. Renewability**

In the world energy structure, human beings are still mainly utilizing fossil energy. Among them, the composition of oil consumption is 41%, natural gas is 23%, and coal is 27% [8]. Due to the non-renewable nature of fossil resources, it is calculated that these fossil energy reserves will go to depletion around the late 21st century to the early part of the next century. By then, mankind will usher into a very serious energy crisis. The interruption of the chain of fossil energy sources and raw materials will probably lead to a world economic crisis, which will affect the development course of the whole society. On the other hand, solar energy is almost inexhaustible for human beings, and solar photovoltaic power generation can make good use of this feature to provide human society with an almost constant supply of electricity, helping human beings to solve the problem of energy crisis. crisis.

### **4. Disadvantages**

#### **4.1. Low Efficiency**

##### **4.1.1. Low energy density**

Although the Sun radiates a gigantic amount of energy to the Earth, the real solar energy can reach the land surface only to reach the earth's range of solar energy about 10%. Because the earth's surface area is huge large and most of which is covered by the ocean, the unit area of the land with direct access to the sun's energy is relatively small. The greatest value of irradiance on the earth's surface, which is typically stated in terms of solar irradiance, is approximately 1.2 kW/ m<sup>2</sup>, but the vast majority of locations and the majority of the sunny period have values lower than 1 kW/ m<sup>2</sup>. Utilizing solar energy actually involves gathering and using low-density energy.

#### **4.1.2. Low conversion efficiency**

Solar cell modules are the most fundamental building block of photovoltaic power generation. The ratio of light energy transformed into electricity is referred to as the photovoltaic power generation system's conversion efficiency. Currently, crystalline silicon photovoltaic cells have a conversion efficiency of 13% to 17% while amorphous silicon photovoltaic cells only have a conversion efficiency of 5% to 8%. As the photoelectric conversion efficiency is too low, resulting in a low the photovoltaic power generation power density, it is difficult to engineer a high power generation system. Therefore, the low conversion efficiency of solar cells is a bottleneck that hinders the large-scale promotion of photovoltaic power generation.

#### **4.2. Environmental Pollution**

Crystalline silicon cells are made using an energy- and highly-polluting technique. Pure silicon serves as the primary raw material for crystalline silicon cells. Sand ( $\text{SiO}_2$ ) is the primary form of silicon, which exists in the earth's crust and is the second most plentiful element after oxygen. In order to turn silica sand step by step into crystalline silicon with a purity of 99% or more, it needs to go through a number of chemical and physical processes, which not only consumes a large amount of energy, but also causes a great amount of environmental pollution.

#### **4.3. Instability**

##### **4.3.1. Intermittent operation**

On the surface of the earth, the photovoltaic power generation system can only generate electricity during the day, not at night, which is inconsistent with people's electricity needs.

##### **4.3.2. Impact of environmental and climate change**

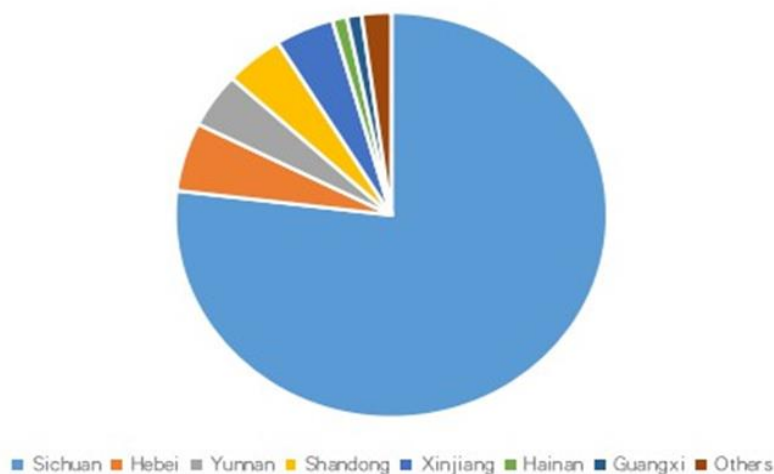
The sun's radiation, which is the source of energy for solar photovoltaic power generation, is highly influenced by the earth's environment, and persistent rain, snow, clouds, and fog will have a negative impact on the system's ability to generate electricity. In addition, environmental factors have a significant impact. The most notable aspect is that airborne particles, such as dust and other particles, collect on the surface of solar panels, blocking some of the light irradiation, decreasing the efficiency of the battery module, reducing power generation, and more seriously harming the battery panel.

#### **4.4. Wide Area**

Each 10kw photovoltaic power generation covers an area of around 100 square meters, with an average power generation per square meter area of 100 w, due to the low energy density of solar energy, which necessitates the photovoltaic power generation system to cover a big area. As photovoltaic building integrated power generation technology matures and develops, an increasing number of photovoltaic power generation systems can be used on the roofs and elevations of buildings and structures, which will eventually eliminate the shortage of photovoltaic power generation land. the lack of a sizable PV power generation area.

Chalcogenide-type solar cells' efficiency cannot increase past a certain point, and the current they produce is extremely low and insufficient to meet today's demands for high-intensity, high-efficiency electricity. Thus, the direction and scope of use has certain limitations and cannot be popularized. Furthermore, the reserves of chalcocite is not sufficient, leading to a difficult mass production [8]. Fig. 1 is the comparison of Titanium Ore Production in China 2018.

Comparison of titanium ore production in China 2018



**Figure 1.** Comparison of Titanium Ore Production in China 2018. (Picture credit: Original)

## 5. Recommendations

### 5.1. Reduce Carbon Emissions

The basic process of solar photovoltaic power generation technology lies in "solar energy → heat energy → electricity", which involves a variety of subdivided technologies in the whole process, and needs to be supported by hardware [9]. Although the solar energy technology is still being updated, the utilization rate of solar energy is still low due to the limitations of the technology. The relevant manufacturing industry should refine the manufacturing level in the future to ensure the precision of manufacturing, control the quality of products from the source, and minimize the loss of raw materials in the production process without affecting the quality of products, so as to reduce costs and expand the scale of use.

### 5.2. Policy Level

The necessary classification regulations are advancing together with the growth of the solar photovoltaic energy generation sector. Still, it should be clear that the coverage of the relevant policies is still limited, which is generally confined to the level of guiding policies, R&D support policies, and market guidance policies [9]. In this setting, it is challenging for the solar photovoltaic power generation business to completely unleash its potential. The government can provide certain policy support for the solar power generation field in the subsequent development, so as to encourage the healthy competition and development of the whole industry.

### 5.3. Industrial Service System

The solar power business currently only has a small volume, and the chain's integrity is insufficient. This makes it difficult for solar power generation to get objective feedback in the development of core technologies, and the research and development of technology lacks an accurate guidance. This will affect the quality of product services and the development of the industry [9]. The relevant industries should collaborate to advance solar power generating technology, promote solar power generation, and increase the scope of its usage in the process of future growth. This will also help to better identify the problems existing in the whole industry in the subsequent development periods [10, 11].

## 6. Conclusion

Solar power holds great promise as an ideal energy source. To obtain electricity from solar energy, light energy needs to be converted into electricity, which is completely different from the principle of other power generation methods. Compared with the fossil energy sources used in the past, it has many advantages such as cleanliness and stability, which is very consistent with the current human requirements for new energy sources. However, due to the limitations of the current technology, solar photovoltaic power generation also has the disadvantages of low efficiency and limited scope of use, hindering its way to becoming the main source of energy for human beings. In order to make solar power generation really reach a practical level, the relevant fields need to develop a higher conversion efficiency using less raw materials, thereby reducing the cost of power generation. This paper has explored both the merits and drawbacks of solar photovoltaic power generation, providing valuable insights for its continued development.

## References

- [1] Ye J.S., Xie Z.X., China Electric Power Encyclopedia, China Electric Power Press, Beijing, 2001.
- [2] Jiang R., Xiao L., Silicon-based solar cells and materials, new material industry, 2003, 116 (7): 8 - 13.
- [3] Ding H.C., Gao L.F., Ma B., World solar photovoltaic market in 2003, Renewable energy, 2004, 000 (006): 71 - 72.
- [4] Sun Y., Wang J.Q., Du Z.F., et al., Study on Cis and cigs thin film solar cells, Acta energiae solaris sinica, 2001, 22 (2): 193 - 195.
- [5] Huang Q.J., Lin J.P., Wei C.H., et al., Application research and progress of silicon solar cells, Development and application of materials, 2009, 24 (6): 93 - 95.
- [6] Li F., Chen Z.H., He M.Q., et al., Water Resources and Power, 2011, 29 (12): 188 - 206.
- [7] Li C.P., Zhang T.Y., Zhou F., Electrical Engineering Materials, 2006, 03 (2006): 45 - 48.
- [8] Liu Z.X., Liu Z.Q., Huang W.J., Key points and measures for environmental pollution control of fossil fuels in China, Resources and Industries, 2005, 7 (5): 49 - 52.
- [9] Ning D, Gao J.C., Significance and prospect of developing solar photovoltaic power generation, Journal of Northwest University of light industry, 2002, 020 (001): 82 - 84.
- [10] Shi J.J., Wei H.Y., Wu H.J., et al., Study on heterojunction characteristics of perovskite solar cells with high efficiency hole-free transport materials, The 29th Annual Conference of the Chinese Chemical Society, 2023.
- [11] Li J.F., Niu A.Y., Problems and improvements in the application of solar thermal power generation technology, Low-carbon world, 2021.