# The Application of Solar Energy and its Economic and Environmental Impacts

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**Abstract.** The energy demand is constantly increasing, and the global energy crisis is becoming increasingly prominent. Solar photovoltaic power generation, as an emerging green energy source, has attracted increasing attention. This article studies the application of solar energy and its economic and environmental impact. Through comparative analysis, review analysis, and practical application analysis, this article explores the advantages and disadvantages of solar energy applications, the application prospects of solar photovoltaic power generation, as well as the challenges and problems faced. In addition, this article also analyzes the current economic development status of the solar energy industry, predicts its future development trends, and proposes strategic recommendations. The research results indicate that the development of solar energy is necessary, especially after a comprehensive analysis of its advantages and disadvantages. The advantages should be further utilized, while the disadvantages need to be avoided. The widespread application of solar photovoltaic power generation has significantly improved people's quality of life and become an indispensable part of daily life. Despite the economic, environmental, and technological challenges faced by the solar energy industry, the continuous improvement and technological progress of the photovoltaic industry chain through learning from experience, overcoming obstacles, and rapid development provide positive prospects and strategic directions for the future application of solar energy.

**Keywords:** Solar energy, economy, environment, challenges, development.

## 1. Introduction

Solar energy is a renewable energy source that refers to the thermal radiation energy of the sun, mainly manifested as sunlight. The energy of solar energy comes from the enormous energy released by the fusion of hydrogen nuclei inside the sun at ultra-high temperatures. The vast majority of the energy needed by humans comes directly or indirectly from the sun.

Solar energy is a clean and renewable energy source, so scientist Zhao Yuwen has made great contributions in the field of solar photovoltaics. He is one of the pioneers and founders of solar photovoltaic technology. He promoted the development of the solar photovoltaic industry from scratch and from small to large. Research in various aspects such as photovoltaic materials, photovoltaic devices, and photovoltaic systems has played an important role in the technological level and international competitiveness of the solar photovoltaic industry. For example, he has achieved many achievements in the research and development of high-efficiency crystalline silicon solar cells and amorphous silicon solar cells, providing technical support for the development of the solar photovoltaic industry. With the continuous increase in human energy demand and the gradual depletion of traditional fossil fuels, humans are seeking new energy alternatives. Solar photovoltaic power generation, as an emerging green energy source, has attracted increasing attention [1, 2]. The problem of energy shortage and environmental degradation is becoming increasingly severe worldwide, and countries are actively seeking renewable green energy to solve this problem.

This article elaborates on the widespread application and significant importance of solar energy on a global scale. This article aims to emphasize the role of solar energy in alleviating energy shortages, reducing environmental pollution, and promoting economic development. By improving technological level and policy support, the utilization of solar energy can accelerate development, thereby achieving cleaner and more sustainable energy goals

## 2. Advantages and Disadvantages of Solar Energy Applications

### 2.1. Advantages

Renewable energy: Solar energy is a renewable energy source that can be continuously obtained as long as the sun exists. The total amount of solar energy received by the Earth each year is enormous. It is estimated that the solar power reaching the Earth's surface is about 173000 terawatts, far exceeding the total global energy demand.

Environmentally friendly and pollution-free: In the process of generating energy, almost no greenhouse gas emissions are produced, which does not cause pollution to the environment and helps reduce dependence on traditional fossil fuels such as coal, oil, and natural gas, thereby alleviating environmental problems such as global warming.

Widely distributed: Solar energy resources are widely distributed, whether in remote areas or cities, as long as there is sunlight, solar energy can be utilized. This provides a feasible independent power supply solution for some remote areas far from the power grid, such as mountainous areas, islands, etc.

### 2.2. Disadvantages

Low energy density: Solar energy has a relatively low energy density and requires a large area to collect sufficient energy. For example, to meet the electricity needs of an ordinary household, it may be necessary to install solar panels ranging from several square meters to tens of square meters on the roof. Compared to gasoline, gasoline has a very high energy density, approximately 46MJ/kg. This makes gasoline the main fuel for traditional fuel vehicles, providing them with a longer range. However, gasoline combustion produces a large amount of pollutants and greenhouse gases, which have a serious impact on the environment. Moreover, hydrogen has a high energy density of approximately 142MJ/kg, making it a highly promising clean energy source [3]. However, the storage and transportation of hydrogen is a challenge that requires special high-pressure vessels or low-temperature technology, which increases the cost and technical difficulty of using hydrogen.

Intermittent intensity: The acquisition of solar energy relies on sunlight, and the energy that cannot be obtained or obtained is very limited at night and on cloudy days. This requires supporting energy storage devices (such as batteries) to store excess energy to meet continuous electricity demand, increasing the cost and complexity of the system.

High initial investment cost: The purchase and installation of solar equipment (such as solar panels, inverters, etc.) require a high initial investment. For some households and businesses, it may be a significant expense, although it can save energy costs in the long run, the initial capital investment may become an obstacle to promoting the application of solar energy.

## 3. Application of Solar Photovoltaic Power Generation

### 3.1. Application in the Field of Residential Construction

Solar water heater: uses a solar collector to absorb solar radiation energy, convert it into heat energy, and provide hot water for residential use. Solar photovoltaic power generation: converting solar radiation into electrical energy through solar panels to provide electricity for residential buildings. Solar powered air conditioning: An air conditioning system powered by solar energy to achieve cooling and heating in residential areas. Solar lighting: Using solar power generation systems to provide lighting for residential areas and save energy.

### 3.2. Application in the Field of Commercial and Public Facilities

Solar photovoltaic power generation system: providing clean and renewable electricity for commercial and public facilities. Solar hot water system: meets the demand for large amounts of hot water in commercial and public facilities, and reduces operating costs. Traditional solar energy

utilization technologies include photovoltaic utilization technology and photothermal utilization technology. Among them, photovoltaic utilization technology mainly utilizes photovoltaic cells to convert spectral bands in the national spectrum of solar energy with energy higher than the battery band performance into electrical energy to achieve the utilization of solar energy. Solar street lights: Using solar energy to provide electricity for street lights, achieving energy conservation and environmental protection. Solar powered billboard: The billboard is powered by a solar power generation system to showcase a green corporate image. The electricity, lawn lights, public lighting, as well as some air conditioning and hot water supply for the Olympic Village, Olympic Park, and Olympic venues of the 2008 Beijing Olympics will be provided by solar energy. The Beijing News reported that yesterday morning, the Beijing Solar Energy Technology Application Demonstration Project, a leading project of the Olympic demonstration project, made its debut to the media. This heavily invested base with large-scale solar photovoltaic grid connected power generation systems and other solar energy utilization equipment will prepare for the large-scale utilization of solar energy for the Beijing Olympics

### 3.3. Applications in the Field of Transportation

Solar-powered cars: Using solar energy as a power source to drive cars and achieve low-carbon travel. Solar-powered vessel: providing electricity to the vessel through a solar power generation system, reducing fuel consumption. Solar-powered aircraft: Utilizing solar energy to provide power for the aircraft, achieving green aviation. Solar charging station: providing clean and renewable charging services for electric vehicles, etc. With the popularization of new energy vehicles and the development of smart transportation, the application of 4G wireless solar power integration solutions on highways is becoming increasingly widespread. This solution combines solar power supply and 4G wireless communication technology to provide a green energy solution for highway monitoring systems that does not require digging trenches or burying wires, and does not consume mains electricity. The use of solar monitoring systems on highways requires compliance with relevant standards and regulations to ensure their safe and reliable operation.

## 4. Challenges and Issues of Solar Photovoltaics

### 4.1. Technical Challenges

Material characteristic limitations: Currently common solar cell materials, such as crystalline silicon, have an upper limit on their theoretical conversion efficiency. The highest conversion efficiency of monocrystalline silicon solar cells in the laboratory is around 26%, while polycrystalline silicon solar cells are slightly lower at around 20%. However, in actual large-scale production and application, the conversion efficiency will be even lower, usually between 15% and 20%. Although emerging perovskite solar cells have high theoretical conversion efficiency potential, comparable to commercial silicon solar cells, and can even exceed 23% under laboratory conditions, they still face stability issues in practical applications and are still some distance away from large-scale commercial applications [4].

Temperature effect: Solar panels generate heat during operation, and an increase in temperature can lead to a decrease in their conversion efficiency. Generally speaking, for every 1 ℃ increase in temperature, the power generation efficiency of solar cells will decrease by about 0.3% -0.5%. For example, in the hot summer, the surface temperature of solar panels may reach over 60 ℃, and the efficiency will be significantly reduced compared to the standard test temperature of 25 ℃ [5].

### 4.2. Economic Challenges

On December 8th, Sha Xiaolin, Chairman of Nantong Johnson Optoelectronics Technology Co., Ltd., announced in Shanghai that the company's use of amorphous silicon solar thin film cell production technology is expected to break the high cost and low output situation of solar power generation. It is expected that the grid price of photovoltaic thin-film cells can be reduced from 4

yuan to 1 yuan per kilowatt hour within two years, which is close to the grid price of thermal power generation in Europe and Japan, thus promoting the promotion and popularization of solar power generation. Sha Xiaolin also announced that the company has invested $25 million to introduce the world's most advanced 25 MW amorphous silicon solar thin film cell production line from the United States, which has recently entered the installation and commissioning stage. It will start mass production in January next year. Industry insiders point out that this is mainly due to the continuous rise in raw material prices of crystalline silicon, and solar power companies are turning to produce thin-film cells using amorphous silicon as raw material to reduce costs. It is reported that solar energy, as a green and clean renewable energy source, has been favored by many countries today. Many European countries have implemented "rooftop plans" to combine solar power generation technology with buildings. However, this approach is not conducive to equipment maintenance and the cost is also high. Johnson Optoelectronics revealed that the company is selecting a site in the open desert area in the west, and plans to build a batch of 1 to 5-megawatt large-scale solar power stations in Gansu, Inner Mongolia, Xizang, Xinjiang, and other provinces and regions within three years. Such centralized operation will lead to higher production efficiency [6].

### 4.3. Environmental Challenges

#### 4.3.1. Environmental impact during the construction phase of photovoltaic power generation projects

The main tasks during the construction phase of photovoltaic power generation projects include the construction of power station buildings and supporting infrastructure, the construction of access and station roads, and the installation of photovoltaic power generation equipment. Similar to most construction projects, photovoltaic power generation projects also encounter the following environmental impact issues during the construction process: disturbance to soil structure. During the project construction process, the operation of material transportation vehicles and heavy engineering machinery, construction of internal and external roads, installation and setting of inverter and boost distribution boxes, laying of underground pipelines, and construction of extensive array foundations all cause disturbance to the original surface soil on site and nearby areas, resulting in mixing between various soil layers in the project area, significantly increasing the area of exposed soil on the surface, and leading to environmental problems such as dust flying and soil erosion. In addition, the construction of permanent buildings in the project will also cause permanent changes in the land use type where they are located, resulting in the loss of their original ecological functions. The impact on natural organisms the environmental impact mainly includes two aspects: one is the impact and destruction of surface vegetation in the construction area. For example, the implementation of construction processes such as site leveling and building foundation construction often requires the removal or burial of surface vegetation in the affected areas, resulting in a significant decrease in surface vegetation coverage in the location of photovoltaic power generation projects. As an important component of the local ecosystem, the reduction of surface vegetation coverage will inevitably have a direct impact on the species diversity and microclimate of the project area. On the other hand, the noise generated during the construction process, as well as frequent activities of personnel and machinery, will significantly affect the habitat comfort of natural organisms in the surrounding areas of the site, reduce the living range of amphibians and reptiles, and thus affect the diversity and ecological balance of natural organisms in the area.

#### 4.3.2. Environmental impact during the operation phase of photovoltaic power generation projects

Based on tracking and investigation of multiple photovoltaic power generation projects, it has been found that photovoltaic power generation projects also have different forms of environmental impacts during the operation phase. Specifically, exhaust gas pollution is more severe, and large-scale photovoltaic power stations are often built in remote areas with sparse population. To meet the food and accommodation needs of on-site staff and the reception needs of project visitors during project

operation, these remote photovoltaic power stations usually have canteens. The exhaust gas pollution generated during the operation phase of photovoltaic power generation projects mainly comes from the smoke generated during the use of canteens. Taking a medium-sized photovoltaic power station with a daily dining capacity of 30 people as an example, if the per capita consumption of edible oil is set at 25g/d, the amount of oil fume volatilization is set at 3% of the oil consumption [7]. The purification rate of the canteen oil fume purification equipment is 60%, so the daily oil fume emission of the photovoltaic power station is 1.62kg/a, with an emission concentration of 1.8mg/m3. These continuously emitted kitchen oil fumes contain various harmful substances, which will have adverse effects on the air quality of the project location.

Wastewater pollution, during operation, daily life of on-site staff, and regular cleaning of photovoltaic modules all generate wastewater containing toxic and harmful substances such as SS, COD, and NH3-N. Taking a photovoltaic power station with 15 residents and a photovoltaic module area of 750000 square meters as an example, if the staff in the station use water normally every day and the photovoltaic modules are standardized to be cleaned once every six months, after scientific calculation, the annual sewage and pollutant emissions generated during the operation phase of the photovoltaic power station are shown in Table 1. It can be seen that if there is a lack of scientific and proper sewage treatment measures during the operation of photovoltaic power generation projects, it will cause a certain degree of damage to the soil and water environment of the region. During the operation phase of solid waste pollution, the on-site staff of photovoltaic power plants will inevitably generate different types of solid waste in their production and daily lives, such as household waste, discarded battery modules, and waste oil generated from equipment maintenance and repair. If these solid wastes cannot be properly disposed of, they will also cause a certain degree of damage to the ecological environment.

**Table 1.** Comparison of domestic sewage and cleaning wastewater.

| Wastewater type | Production volume (m ³/a) | Types of pollutants | Production volume (t/a) | Generate concentration (mg/L) |
|---|---|---|---|---|
| domestic sewage | five hundred and fifty-eight point five | Cod | 0.168 | 300 |
| | | NH3-N | 0.020 | 35 |
| | | SS | 0.112 | 150 |
| Cleaning wastewater | three thousand two hundred and thirty-two | SS | 0.650 | 200 |

## 5. Application Prospects of Solar Photovoltaic Power Generation

In the next decade, the market trend of solar cells will undergo significant changes. Before 2010, solar cells were mostly used in independent photovoltaic power generation systems. However, from 2011 to 2020, China's photovoltaic power generation market will shift from independent power generation systems to grid connected power generation systems, including desert power stations and building roof power generation systems [8]. The market share forecasts for solar cells in 2010, 2020, and 2050 are shown in Table 2.

**Table 2.** Market distribution of solar cells and comparison of future and past market shares.

| Market classification | Market share in 2010 | Market share in 2020 | Market share in 2050 |
|---|---|---|---|
| Rural electrification | 60 | 10 | 5 |
| Communication and Industry | 10 | 15 | 7 |
| Solar photovoltaic products | 10 | 15 | 8 |
| Photovoltaic grid connected products | 20 | 60 | 80 |

Solar photovoltaic power generation can provide a large number of employment opportunities and stabilize society. The ongoing research and development project of several-fold reflective concentrated photovoltaic power generation technology can solve employment for about 800 people when the large-scale production line reaches 2MWp, and about 4000 people when the production

capacity reaches 10MWp. With the rapid development of China's solar cell industry, thousands of production personnel, scientific and technological personnel, sales personnel, and management personnel have flooded into this thriving and expanding industry. It is expected that by 2020, solar photovoltaic power generation will provide more than 20 million job opportunities for China, and solar photovoltaic power generation will become one of China's energy pillar industries. Simultaneously driving the rapid development of related industries such as electronics, transportation, machinery, electrical appliances, and services. By 2020, with the significant enhancement of comprehensive national strength and the rise of the photovoltaic industry, China will build super large-scale solar thermal power stations and solar photovoltaic power stations. Among them, solar photovoltaic power stations with a capacity of over 10MWp include desert power stations, large-scale photovoltaic hydrogen production, large-scale seawater desalination, large-scale integrated solar photovoltaic buildings, large-scale photovoltaic water pumping stations, photovoltaic electric vehicles, and space power generation. Photovoltaic power generation will become an important component of China's main energy source in the future.

## 6. Conclusion

The full text discusses the application of solar photovoltaic power generation in daily life**,** including residential electricity**,** rural electricity**,** industrial electricity**,** public facility electricity, and the practical application of photovoltaic buildings (BIPV). Explained the technical challenges of photovoltaics, including issues with solar power generation efficiency and energy supply at night and on cloudy days, as well as economic challenges such as high costs of solar power generation and grid access and energy storage costs, the environmental impact of solar panel manufacturing, and the disposal of waste solar panels. The continuous deepening of research in the field of photovoltaic power generation and the gradual improvement of the conversion efficiency of photovoltaic cells indicate that the continuous improvement of the photovoltaic industry chain and varying degrees of technological progress have good application prospects**.**

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