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The Impact of Renewable Energy on Environmental Protection in China-Taking Solar PV as an Example

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Abstract

Renewable energy has significant advantages over traditional energy sources. It is often called "environmentally friendly green energy", which is considered to be free of environmental pollution and disruption. However, the process of its development and utilization needs human interventions, which is a long-term and complicated systemic project. From the renewable energy supply upstream and downstream industry chain, zero carbon emissions and zero pollution cannot be achieved. There are high pollution costs and ecological damage risks. The front-runner of renewable energy is photovoltaic power generation. It is smaller than the traditional fossil energy generation for the environment. To achieve photovoltaic power generation, a huge photovoltaic industry chain is needed to do support. According to the IEA (International Energy Agency) report, 80% of the global solar photovoltaic industry manufacturing is concentrated in China. The electricity used by the industry manufacturing, the carbon dioxide emissions to the atmosphere, and the three wastes (wastewater, gas, and sludge) generated during the manufacturing process become the environmental problems that China needs to eliminate as a production supplier.

Keywords: Renewable energy; Photovoltaic power generation; Photovoltaic industry chain; Environmental protection; Photovoltaic future

Introduction

At present, the momentum of China's economic take-off is unstoppable, and a stable and environmentally friendly energy supply is the basic guarantee for economic development. Being different from China's long-term reliance on fossil energy such as coal and oil, which has led to resource depletion, environmental degradation and climate change, renewable energy is environmentally friendly, green and sustainable. 2021's authoritative United Nations Climate Conference has once again released the idea that building renewable energy facilities is an important step in reducing carbon emissions globally in the future. This has conceptual commonalities with China's announcement in October 2021 that carbon should be "peaked in 30 years" and "neutralised in 60 years", which is an important historical strategy to create a green, low-carbon and recyclable economic development system and to expand the proportion of renewable energy supply and consumption. It is the concept of creating a green, low-carbon and recyclable economic development system, increasing the proportion of renewable energy supply and consumption, reducing carbon emissions and enhancing the sustainability of the ecosystem. The use of renewable energy for power generation has become a major trend and a choice for human development.

Background and significance of the study

"The sun is the source of energy for the growth of all things", and some scholars say that the sun has been used for 4.6 billion years and still has 5 billion years to continue supplying energy. All the environments on which humans have depended for so long, including the fossil energy, are formed by direct or indirect conversion of solar energy. In the middle of the last century, photovoltaic cells were first developed using monocrystalline silicon at the Bell Research Institute in the USA, ushering in a new era of solar power generation for human energy. These photovoltaic cells are arranged in series to form a large-area matrix, which forms a power station together with controllers, inverters and other auxiliary materials. These power stations are long-lasting, clean and safe, environmentally friendly and energy-saving, and do not require a lot of follow-up maintenance work. If they can be put at the service of mankind, the newly developed solar photovoltaic power generation will undoubtedly bring new expectations to mankind against the background of a series of environmental problems caused by the exploitation of traditional fossil energy sources.

With the rapid development of the photovoltaic industry in

more than half a century, two modes of expression have been formed in its downstream power stations. One is centralised photovoltaic power stations, which are mainly built in deserts, Gobi and other areas where ecological resources are scarce and the environment is not suitable for human habitation; the other is decentralised photovoltaic, which is mainly built on the roof of the buildings, the top of the plant, the top of the vegetable shed, above reservoirs or fish ponds and other small areas that can be fully utilized. In general, photovoltaic power stations are not limited in size, and they are flexible in installation, safe in operation, easy to maintain, large in space utilisation, and friendly in harmony with the environment.

The carbon emissions from photovoltaic power generation are far from those of traditional fossil energy sources, reaching only about 10-20%, and will be a strong grip for China to achieve its dual carbon targets in the future. Over the past decade or so, our country's photovoltaic industry has taken an incomparable path in cost control, with costs dropping to 90% of previous levels. In the local 14th Five-Year Plan, several cities clearly indicated that vigorously expand photovoltaic production capacity and increase the construction and investment of photovoltaic sites, especially in coastal cities such as Zhejiang, Jiangsu and other regions walking in the front of industrial research and development. According to the estimation of research institutions under the China Development and Reform Commission, the installed capacity will be expanded by at least half in 25 years, and 40% of domestic power will come from photovoltaic power generation in 50 years. Looking forward, the future of photovoltaics is good. However, an economy that moves forward too blindly is vulnerable to environmental repercussions. History has taught us that economic development must be safe and environmentally friendly. It is the ultimate goal for mankind to live in harmony with nature, to share the environment and to build ecological diversity and sustainability.

As the PV industry continues to expand, and the amount of equipment and facilities it owns increases, we need to understand and analyse the role and impact of PV on environmental protection. From the source to the end of the industry, we need to recognize the weaknesses in environmental protection and identify the bright spots. We will use a rational and scientific approach to guide the photovoltaic industry to avoid environmental risks and to improve the extensive and sustainable contribution of photovoltaics to environmental protection.

Current status of domestic and international research on renewable energy

Current status of foreign research on renewable energy

EU: Germany, with the largest population coefficient in the EU, for example, has relatively leading renewable energy generation technology and development concept of environmental protection. In Germany, as the use rate of land resources is high, photovoltaic is mainly distributed power generation, which is widely used on building roofs. Wind power is mainly arranged in the hills and some areas near the coastline, and biomass power generation mainly exists in rural areas in the form of biogas power generation and biomass burning power generation. In the first half of 2022, these new sources of energy provided nearly 50% of Germany's electricity. In recent years, Germany has revised the Renewable Energy Act five times, and the requirements for the share of renewable energy power generation are increasing each time. The latest amendment proposes that it aims to reach 65% of the electricity generated in 2035 and reach 80% of the electricity supplied by renewable energy in 2050. Germany has a high self-sufficiency and wide distribution of renewable energy, which has led to the orderly development of local industries and the environment.

UK: The UK is at the forefront of renewable energy technologies and applications and is a country with a very rich offshore wind industry. The UK authorities announced that in 2020, the UK's annual renewable energy generation was higher than fossil energy for the first time, with a 43.1% share of electricity generation. By the end of 2021, the UK has been the largest country in Europe with 12.7GW of offshore wind energy on the grid. Besides, a UK power analysis company said that renewables will be the main source of electricity generation in the future. The UK BEIS (Department of Energy and Industrial Planning) has stated that in 2021, renewable energy generation will be 121.9TWh, which is indeed 9.5% lower than that of in 2020 due to the impact of the epidemic and the weather. However, 2021 is still the second highest in the UK in terms of renewable energy development over the years.

The US: The US Energy Agency announced that 20 percent of its electricity production in 2021 would come from renewable sources, amounting to 8,000TWh. The country's future plans are to increase the share of wind and solar power in the long term and to promote the rapid development of renewable energy in order to reduce its dependence on fossil energy. Solar power, in particular, will become the main force of renewable energy generation in the future. Renewable energy has been better practiced and used in the United States, and environmental pollution and damage to the atmosphere have improved with the development of renewable energy.

The development status of renewable energy in China

I. Development stage

a) From 1949 to 1994, China mainly focused on biogas and hydroelectric power generation, and less on other renewable energy sources for gradual and independent innovation. During this period, the hydropower industry developed rapidly. By the end of the 1970s, China was mainly developing hydropower, and the whole storage capacity had reached about 19 million KW, with an annual production of nearly 50 billion KW/H.

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b) 1995-2007, from technology imitation to innovative transition stage. At this time China began to pay attention to the development of energy systems about wind, geothermal, solar and other work. Due to the late start, lack of experience, and relevant legal policies in a blank state, there is a certain gap between China's renewable energy technology and that of foreign countries. In response to the development needs, China implemented the Law of the People's Republic of China on Energy Conservation in 1998 and the Law of the People's Republic of China on Renewable Energy in 2006. At the same time, it began to refine various plans, aiming to improve the relevant objectives and tasks.

c) Before 2012, China's annual wind and solar power generation accounted for less than 20% of the country's new electricity consumption. However, after 2012, renewable energy generation continued to increase. In 2014, China's wind and solar power generation exceeded the newly increased electricity consumption for the first time, and its installed capacity ranked first in the world. In the same year, great breakthroughs were made in photovoltaic and biomass power generation. At this time, China is mainly in the creative imitation stage. While developing, it also adjusts and optimizes all aspects, and gradually attaches importance to independent innovation.

II. Development status

In September 2021, the country announced its "double carbon target" strategy, which indicates that by 2025, the proportion of renewable energy generation will reach about one-fifth of consumption. In June 2021, a notice on feed-in tariffs was issued, which also mentions that from 2021 onwards, new renewable energy generation projects can be built on a voluntary basis and enter the market. It better demonstrates the value of photovoltaic as green power. Similar policies, regulations and development objectives are aimed at achieving a more comprehensive reduction in dependence on traditional energy sources, increasing the use of sustainable electricity generation, reducing CO2 emissions and achieving truly sustainable development.

As can be seen from (Figure 1), from 2016 to 2021, China's power generation and installed capacity in the field of renewable energy showed a continuous upward trend, and the average growth rate was above 10%. Among them, installed capacity of renewable energy power generation in China has exceeded 1 billion KW last year, accounting for about 25% of the total reserves of power generation units, an increase of nearly 14% from the previous month. In 2021, renewable energy sector of China will generate about 2480 billion kilowatt-hours of electricity, an increase of about 12% year-on-year, accounting for 30% of the total social electricity consumption.

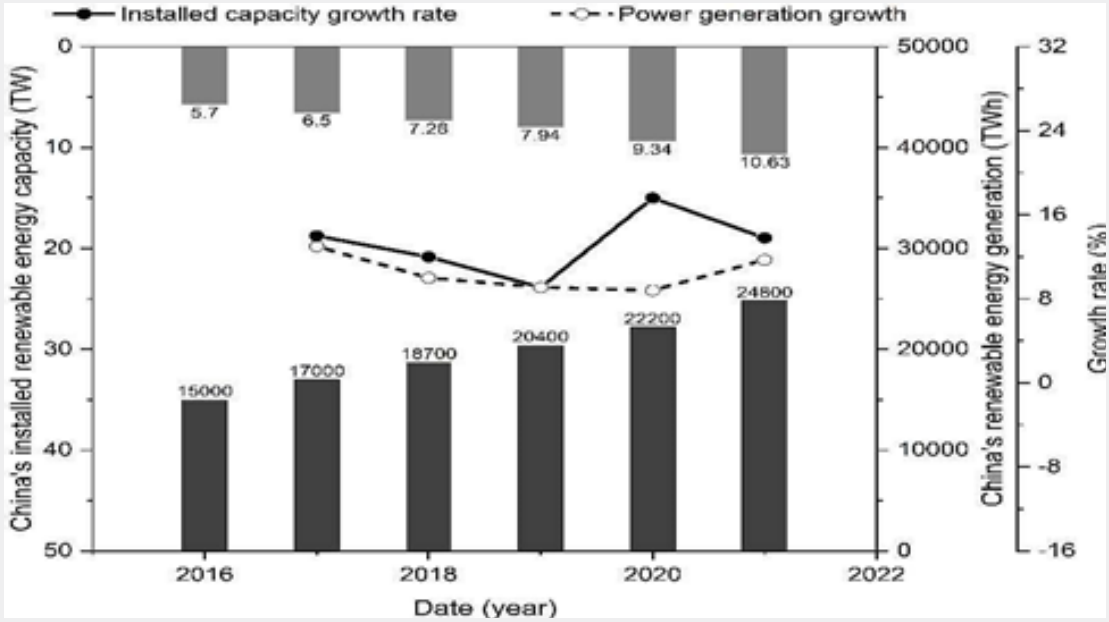

Figure 1: China's renewable energy generation data for the last 6 years.

At present, there are four main types of renewable energy generation in China, involving wind, light, water and biomass. From the aspect of (Figure 2), regarding the proportion of installed scale and the proportion of power generation, the whole scale of wind power generation, photovoltaic power production and water power generation respectively accounted for about 30% of the total scale last year. Besides, its power generation obviously accounted for more than half of the total power generation, and the remaining three types of renewable energy have more room for growth.

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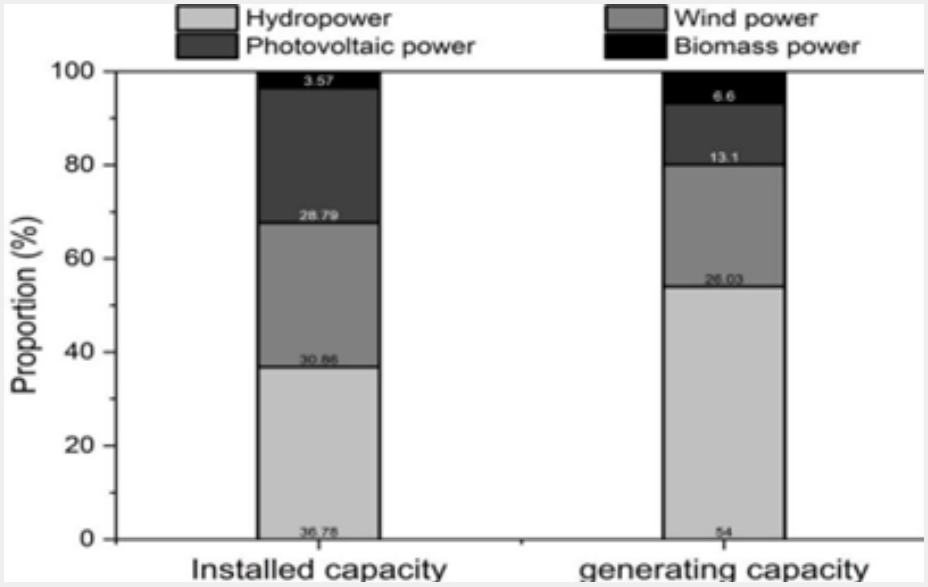

Figure 2: Data of four renewable energy sources in 2021.

Development of the photovoltaic power generation industry

Development stages of the photovoltaic industry in the world

From a global perspective, the photovoltaic industry was mainly affected by the penetration of technology in the European region, led by Germany in the beginning, and mainly showed four stages of development.

1. The period of high growth and development from 2005 to 2010, when the global market for the PV industry was dominated by Europe.

2. From 2011 to 2012, when the global PV industry entered a brief downturn, experiencing overcapacity, trade frictions, the European debt and financial crisis.

3. From 2013 to 2017, during the rising period of emerging markets, China was an outstanding representative of the emerging market. The PV industry in the world once again stepped into a more rapid development track. PV power plant investment continued to increase, and the new installed capacity doubled year after year.

4. In the same year, China introduced the "531 New Deal" and the "Notice on Matters Relating to Photovoltaic Power Generation in 2018", which were the policies of mainland China. The global photovoltaic industry began to usher in the most affordable era since the Internet, China's photovoltaic installation in the global scale was still maintained at a high new scale.

Development stage and current situation of domestic PV industry

a) The development stage of the PV industry in China

The PV industry started late in China, with a total development time of less than 20 years. It has gone through 3 important stages in China.

1. The initial stage is before 2007. The photovoltaic industry in China was mainly driven by policy at this stage. For example, in 2001, the Bright Project was launched in the hope of using renewable energy to solve the painful problem of remote areas without access to electricity. As the scale was restricted and the market was not available, the construction of the PV industry in China was relatively slow at this stage.

2. From 2007 to 2013, it was in the stage of curve development, and the growth of PV installation fluctuated. In order to make a clear statement on the tariff subsidies for reproducible electricity, the country introduced the "renewable energy tariff additional subsidies and quota trading program notice", so that the investment enthusiasm of PV industry chain enterprises was greatly enhanced. From 2009 to 2010, in order to promote the healthy development of the polysilicon industry, the state launched the "PV building application" benchmark project, and issued the "Notice on the Suppression of Overcapacity in Some Industries and the Quota Trading Scheme", hoping to guide the domestic PV industry to adapt to the market development more quickly.

3. After 2014, it was in the steady growth phase. Electricity subsidies and filing systems have boosted the investment enthusiasm.The country has also set up PV poverty alleviation plans and implemented runner-up projects, allowing the PV industry to step into high gear, with annual growth rates remaining at around 25%. Since then, the photovoltaic power generation industry has officially entered a period of stable development.

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b) The current situation of China's photovoltaic industry development

At present, China's photovoltaic technology is improving at a high speed. The cost of photovoltaic electricity production is gradually reduced, while the power trade has more market-oriented advantages, which is predicted in the "Fourteenth Five Year Plan". And photovoltaic machine storage in China will continue to heat up. Throughout the entire energy structure of China, photovoltaic power generation will gradually increase. According to PV industry scholars, in the current normal industry development trend,, China's PV industry can reach 110GW of new installed capacity by 2025, with a large growth space. From 2018 to 2020, the global CAGR (compound annual growth rate) of installed industry shipments was 25.8%, and China reached 20.5%. Driven by policy, China has begun to develop distributed PV in recent years, which is different from centralized PV power stations in the past. It can be seen from (Figure 3) that distributed household PV has gradually become a new force for PV development in recent years. Especially in 2021, China announced the policy of "promoting the development of distributed PV in the whole county". It is estimated that the average annual distributed PV will enjoy rapid development during the 14th Five-Year Plan period.

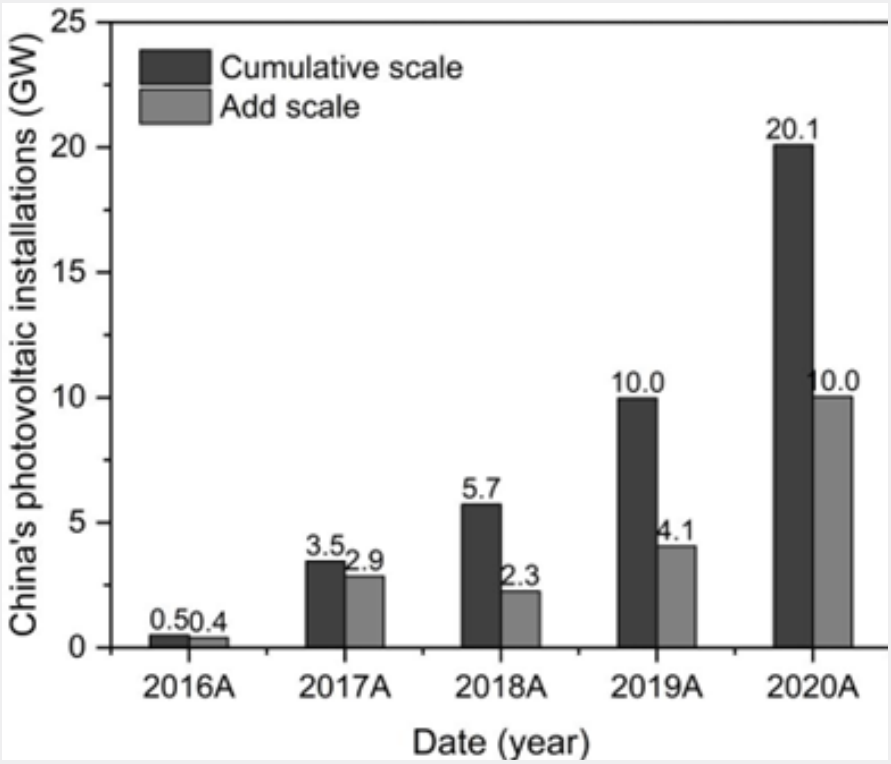

Figure 3: Installed scale of household PV in China (GW).

According to China's relevant planning requirements, the PV industry will also be vigorously developed in a centralized manner. During the "14th Five-Year Plan" period, as a new energy source, PV has a large window of opportunity, and the national strategic positioning is high quality, high proportion, market-oriented and large-scale. Large-scale centralised PV projects will be built in Gobi, desert, and desert areas.

China's domestic efforts to break through the technology of the PV industry chain, the gradual reduction in the cost of electricity generation and the initial clarification of the national tariff have led to a booming trend in the development of PV industry. Data from (Figure 4) shows that China reached 306 million kilowatts of PV power generation capacity last year, four times more than the 2016 capacity; By 2021 the capacity reached 325.9 billion watt-hours, seven times that of 2016.

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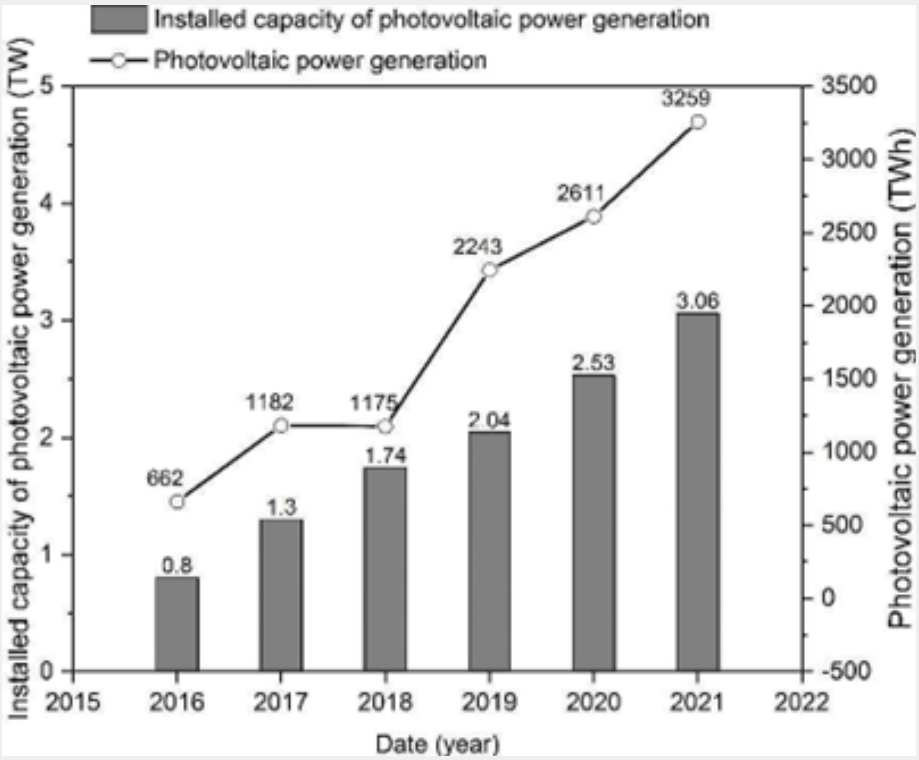

Figure 4: Installed PV capacity and electricity generation.

Analysis of the Environmental Impact of Pollution from the Photovoltaic Industry

Since 2013, the country has been vigorously promoting energy conservation and emission reduction and has rapidly increased the development speed of the photovoltaic industry. By 2017, China's domestic PV production and storage capacity have exceeded that of the European Union. The photovoltaic industry chain is also being gradually upgraded and optimised. The production of photovoltaic panels has four important links, including silicon production and processing, silicon wafer production and photovoltaic cell production. For the first time, it surpassed Japan. Due to its technological and production advantages, the cost of photovoltaic power generation has fallen by more than 90% over the past decade, and China's Development and Reform Commission predicts that by the year of 2050 , nearly 40% of social electricity consumption will be supplied by photovoltaic power generation. China is currently the world's premier and largest PV equipment manufacturing hub, and the upstream, midstream and downstream chains of the PV industry are all in place, with each link being a participant in PV power generation and expecting the industry to create economic value on a stable basis. However, each link also needs to pay attention to environmental issues to meet environmental requirements, so as to achieve sustainable development of the industry and long-term economic development efficiency. This group starts its analysis from the silicon wafers at the front end of the PV industry, and then returns to the recycling of solid waste at the end. As the industry chain is really long and involves a wide range of contents, this group has selected the most representative links to make in-depth analysis and research, in an effort to understand the impact of industrial development on ecological links and polish the contents of this chapter to warn others.

Pollution focuses of battery production in PV industry

Photovoltaic power generation is still most dominated by photovoltaic cells, which are usually made with silicon as the substrate. Because of the relatively high energy conversion rate, cost advantages, long service life and other characteristics, the market produces more monocrystalline silicon or polycrystalline silicon photovoltaic cells. In the original development process, polysilicon was used in the highest proportion. From silicon to the manufacturing process of crystalline silicon panels, there are the following important pollution links.

Silicon processing link

The primary raw material used in photovoltaic cells is ore from nature. From the (Figure 5), we know that silica is the most important raw material for the whole photovoltaic power

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generation industry. After high temperature smelting, purification and a series of complex chemical and physical operations, crystalline silicon with high purity is obtained. It is then drawn into rods to form ingots, which is then cut into wafers to obtain the silicon wafers to make photovoltaic cells.

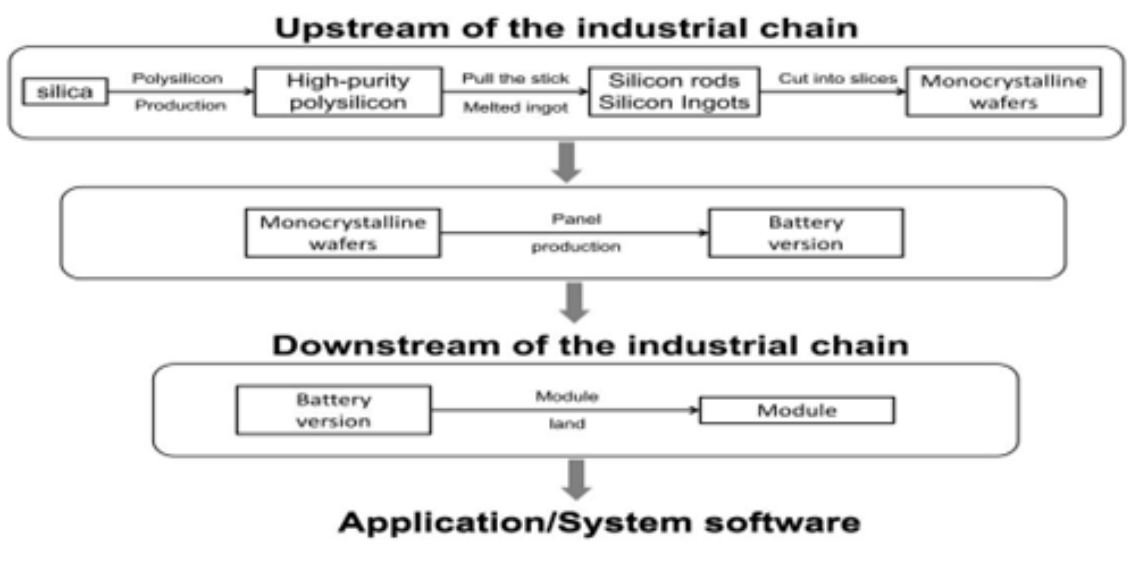

Figure 5: Diagram of the PV cell production industry chain.

The smelting of silica and the purification of crystalline silicon are technically complex and demanding, requiring materials such as coke, charcoal and fine coal to be used in the process to produce a reduction reaction with the silica. The process of smelting silica at high temperatures consumes a lot of electricity, with one tonne of silicon metal consuming around 13,000 kWh of electricity. At the same time, the smelting process produces fumes containing toxic chemicals, which pollutes the environment more and consumes more energy. As the process of smelting silicon is an overcapacity in China, manufacturers usually compete maliciously at low prices, so the price of silicon metal tends to fluctuate more frequently, resulting in many small and medium-sized manufacturers being reluctant or not having the financial strength to invest in building gas treatment equipment. However, manufacturers do not pay attention to the fact that if these gases and waste heat are recovered and treated in the right way, large quantities of silicon micro-powder particles can be obtained and they can be re-sold to generate economic benefits. If the waste heat can be used in an environmentally friendly way, it can also reduce electricity consumption and save economic costs.

At the same time, in the engineering of smelting, most manufacturers still use the more popular Siemens smelting and purification process, which is prone to produce chemical by-products of silicon tetrachloride during operation, being corrosive and irritating. During the production of crystalline silicon, a large amount of wastewater is also produced, containing harmful substances such as silicic acid, silica and hydrogen chloride, which cannot be dealt with properly. If these substances are not handled properly, or if the treatment process is not foolproof, and if the smelter goes out of business as the competitive environment deteriorates, then there will be no one to take care of the contaminated abandonment. Under such circumstances, the local governments of China can not control the situation since they lack funds or technology to deal with it. Eventually, chemical pollutants generated in the production and processing of silicon materials may be discharged into the nature or buried in the soil in an inappropriate way, which would have a more immeasurable negative impact on the local atmosphere, water, natural environment and surrounding ecology.

Making photovoltaic panels

According to scholarly research, the process of making silicon wafers into solar cells requires processing such as fleece making, cleaning, etching and encapsulation, which will produce various chemical wastewater containing acid, alkaline or organic, as well as air pollutants such as ammonia and isopropyl alcohol. Some companies and factories discharge waste water into the environment or the atmosphere in order to save costs or because of loopholes in their own treatment processes. In addition to the corresponding environmental pollution caused by the use of raw materials, the use of other auxiliary elements can also lead to greater environmental pollution. However, pollutants from the production of photovoltaic panels do not receive as much attention as those from the smelting process, and there have been cases of mass incidents caused by improper disposal of waste materials from the production of photovoltaic panels. In fact, the process

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of making photovoltaic panels uses a lot of water, eliminates a lot of gases, and consumes more energy, all of which may cause environmental pollution or break the ring, causing invisible environmental costs to the ecology of the local surrounding life.

The pollution focuses of the power station operation and energy supply link of the photovoltaic industry

Light pollution

"Light pollution" refers to the overall performance of some light that is detrimental to vision, body and natural environment. For example, urban buildings are decorated with large mirror facades, and glass materials are easy to cause light pollution. Solar photovoltaic equipment reflects a certain degree of sunlight during operation. Although light pollution has been reduced with the development of technology, it is still quite difficult to achieve "zero reflection". When the sun's radiation is too strong, the solar panels on the roofs of surrounding houses reflect light and shine brightly, creating environmental pollution from light. Scholars have found that in the long-term white and equal light conditions in work or daily life, human iris cells and retinas will be damaged to varying degrees, and vision will decline faster. The incidence of senile cataract has reached 45%. Some people will also exist dizziness, insomnia, depressed mood, easy fatigue, upset, appetite decline and all kinds of neurasthenia conditions. Generally speaking, photovoltaic cells need to be attached to buildings and placed in a sunny direction. This means that the sunlight reflected by the photovoltaic panels does not reach the ground or the lower floors of the house, but instead shines on high-rise buildings or aircraft pilots, causing light damage. For long-term urban residents, light damage is universal. With the construction of distributed photovoltaic in more and more cities in China, light pollution is not a problem that can be taken lightly. It will indeed pollute the surrounding ecology.

Thermal pollution

Some scholars have studied that the reflectivity of sunlight on the heat collection plate is different from the surface of the earth. There is a significant difference between them. The reflectivity of sunlight on the heat collection plate is likely to cause the temperature of local area to rise or fall. This in turn causes atmospheric circulation, affecting the surrounding environment and causing serious ecological damage. If there is a significant change in atmospheric humidity, there is a risk of surface weathering. In addition, the thermal balance between the surrounding area of the PV plant and the area where the electricity is used can be difficult to maintain, which is why large PV plants are built in sparsely populated deserts and transmitted outwards through the grid. This is why large photovoltaic power stations are built in sparsely populated deserts and transmitted outwards through the grid. In particular, large photovoltaic power stations are at great risk of climate change due to the different heat balance conditions among distant locations. Therefore, thermal pollution needs to be avoided as much as possible. Thermal pollution is also a major environmental risk issue for global climate change.

The focus of pollution in the construction of power stations in the photovoltaic industry

As the planning and design of photovoltaic power stations, the implementation time is relatively long. During the construction period, the surrounding environment is prone to noise, dust, water for daily life, machine construction exhaust and other aspects of pollution.

Pollution from construction lines and equipment

Construction of photovoltaic power station requires the erection of supports, the excavation and filling of cables and wires, as well as the subsequent line maintenance. In the construction phase, building construction, transport vehicles and repair machinery operations, etc. will produce ultra-high decibel noise. Secondly, in the implementation phase of constructing photovoltaic power stations, the transport of vehicles, construction equipment and materials, the pouring of piles and the levelling of the foundations will form the corresponding dust and noise pollution. In addition, the use of construction equipment during construction can also be noisy, which can cause disturbance to the animals living in the surrounding area. In particular, birds, which love a quiet environment, will instinctively leave the site after being exposed to noise, thus leading to a break in the ecological food chain. At the same time, there is usually a microclimate within a larger climate, which is formed by the weather in the soil and vegetation layer, which is about 100m away from the earth's surface in the direction of the atmospheric lead. Besides, the construction of the photovoltaic power station will make the wind and temperature in the construction area significantly lower, and the relative humidity of the air will also change, leading to polution to the local natural environment, climate and scenery. The construction of photovoltaic power plants will result in the fragmentation of the local natural environment and climate, creating a greater risk of fragmentation of the natural ecosystem.

Ecological imbalance around the power station

The construction of photovoltaic power stations can easily cause the ecological environment to lose its original appearance, such as soil erosion, plant damage, changes in the number of plants and animals, and damage to the microclimate system. Firstly, during the construction of photovoltaic power stations, construction activities tend to cause the original topography to be modified, soil and water to be lost, and the original surface water circulation path to be changed. The topography of the site is generally open, so site levelling, dredging and filling of buildings, temporary bulldozing of slopes, etc. are also implemented during construction. In the event of rain, poor drainage channels will produce erosion, which will be detrimental to the surrounding area, and the surrounding drainage channels will also become waterlogged. Secondly, the construction of power stations

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involves the construction of electrical facilities, road surfaces, building structures and fibre optic cables. The above-mentioned construction activities will also cause different degrees of harm to the surface vegetation. For example, in ecologically sensitive areas, the construction of infrastructure such as soil box transformers will destroy the original soil surface and vegetation, thus transforming the land in the area from previously grassland to construction land, resulting in a decrease in the number of plants and an increase in soil erosion. The area where the PV plant is to be built usually requires that no endangered species are present, so the loss of vegetation is mostly in the form of common community structures or weeds with a simple species structure. For ecological sensitivity reasons, if the number of plants and animals on the surface declines, soil erosion becomes more serious and the animals used to inhabit the area have to migrate or die due to the destruction of the food chain, resulting in an imbalance in the ecological environment.

Pollution from waste

The construction of photovoltaic power stations generally involves the following waste: 1) building waste; 2) photovoltaic equipment waste; 3) waste from the daily lives of construction and transportation workers; 4) waste from transportation and operation tools. If these wastes are not properly managed, they can easily be invaded into the soil by rain or dispersed into the natural environment by wind, thus polluting the environment. Therefore, stockpile management becomes extremely important. At the same time, the above waste may also pose a risk of pollution to the surrounding natural environment in terms of reduced air quality.

Battery pollution

Photovoltaic power plants are a system for generating and releasing energy and have many components. Photovoltaic power systems have a limited lifespan and commonly use lead-acid batteries, which contain large amounts of lead, antimony, cadmium, sulphuric acid and other heavy metals and toxic chemicals. According to academic comparisons, in more developed countries, about 5% of the lead used in the manufacture of lead-acid batteries is released into the environment. In developing countries, the figure would be around 22-34%. In the case of large photovoltaic plants, there are professionals available to dispose them, and they are not likely to cause direct pollution to the environment, provided they manage properly. However, domestic photovoltaic systems cannot be disposed of properly because the general population lacks the skills to do so, and because they are too dispersed for after-sales management, coupled with a weak awareness of environmental protection.

Recommendations for the Photovoltaic Industry in Environmental Protection

In order to improve the supply and demand in the rapidly advancing market of the PV industry, mainland China has gradually adjusted its regulatory efforts and implementation measures in the field of environmental protection. Looking at the development of the industry in recent decades, it is true that it has caused certain problems to the ecological environment. And it is not difficult to find that a lot of pollution is caused by human beings because of negligent supervision, or blind development. Of course the overall quality of practitioners needs to be improved and technical level problems need to be solved at the same time. Photovoltaic is the core technology first mastered by high-tech oligarchs in developed countries such as Europe, the United States and Japan. The core advantages of these technologies can not really be mastered by our enterprises or R & D institutions. Although China has overcome and improved Siemens' purification methods after years of R & D. However, in the core technology and enterprise production equipment environment that are truly innovative with the times, there is still a gap compared with foreign countries. The policy background for the development of China's photovoltaic industry is very special. In order to develop the local economy, the local government will generally pay attention to the economy first, and then the national pollution control. For example, the largest silicon material producer in Luoyang was found to be polluting the countryside and rivers, and the problem was only reported by the public, and the problems found were only expressed as the enterprise had carried out treatment of sewage and sludge, which failed to meet the national standards. Although the local government gave such a written explanation, the pollution of the river caused by the accident and the pollution of the surrounding ecological environment did not attract enough attention. Therefore, the government, enterprises and everyone in China need to make efforts to avoid the pollution caused by the industry, to play a positive role in the environment as much as possible, and to truly promote the PV industry zero carbon emission and zero pollution. This chapter puts forward some of the measures and suggestions for the PV industry in terms of environmental protection issues in China for reference.

Improving upstream process technology

China's crystalline silicon production enterprises mostly adopt closed-loop improved Siemens method to produce crystalline silicon materials. They are mostly large enterprises, and their business basically involve a wider range of financial strength, stronger innovation, and more technical personnel. The manufacturing links can basically meet China's environmental requirements. However, the eagerness to pursue economic development throughout the vast territory of China has led many enterprises to adopt the more backward technology of simulating foreign technology, which is not really the "modified Siemens method" technology at all. This directly leads to high energy consumption, pollution of the ecological environment and the generation of three wastes. In the last decade, China's crystalline silicon purification technology has indeed been greatly improved, but it is still not complete. More enterprises are reluctant to take the initiative to replace new technology and equipment due to cost

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issues, and are eventually forced to shut down, go bankrupt or close down. Some enterprises also need the relevant departments to forcefully supervise in order to have some transformation. In view of the above, the following environmental protection measures can be referred to in this section.

Raising the threshold for industry access

Firstly, local governments should take a firm view of long-term development and look at the bigger picture, select high-quality investment enterprises as far as possible, raise the entry threshold for the crystalline silicon industry, and screen out experienced practitioners from the source, who understand management, technology and have sufficient capital flow to set up the enterprise and operate the project. Secondly, the relevant departments will increase supervision and inspection and other management efforts to guide the safe and compliant discharge of waste gas, waste water and slag from enterprises, and randomly check the density of environmental pollution around the enterprises from time to time. For enterprises that would allow the surrounding ecological environment to be polluted, they are ordered to completely rectify the situation and then follow up for approval on whether they can resume production. Those who cause serious pollution and fail to rectify as required may be punished or even banned according to law. These problematic enterprises are also provided with M & A, acquisition and other channels to help them exit the market and industry. In addition, they should coordinate with powerful enterprises that can quickly take over at a lower price to avoid environmental pollution caused by long-term shutdown without any responsibility. Again, the government needs to provide some policy support and set up a special support fund to supervise and encourage crystalline silicon production enterprises to increase investment, continuous innovation, improve the competitive advantage of the industry. Moreover, encouraging the introduction of advanced production equipment and production processes in response to the changing needs of the market, so that the level of environmental protection production of enterprises can meet the requirements and indicators of the department of national environmental protection.

Support leading enterprises to set an example

Despite the rapid development of China's crystalline silicon industry, a production capacity of 505,000 tons was achieved in 2021. The market outlook is positive, and the existing technology can meet the independent research and development, and achieve independent manufacturing of process equipment. However, the core technology is not strong enough, and has been out of the stage of catching up with the giants of Europe, America and Japan. The government should vigorously support China's leading crystalline silicon enterprises, help them increase investment in scientific research, improve process equipment, independent research and development of purification of core technology, optimise production processes as far as possible. The average cost of production should be reduced in the industry, making the industry develop orderly under the role of demonstration companies, avoid vicious competition and low-cost competition regardless of environmental costs. A more cost-competitive price will allow China's crystalline silicon sector to fulfil its global competitiveness and operational potential, and better achieve sustainable development of the industry. Strive for better cost, higher quality and more environmentally crystalline silicon products, which in turn will reduce the damage to the ecological environment.

Waste recovery and recycling

Recycling is an important sustainable development concept. Recycling is not a one-sided reuse, but a process of turning waste materials back into recyclable materials. The proportion of recyclable material varies depending on the material used. The photovoltaic industry produces a large amount of silicon scrap, auxiliary component trimmings, as well as newer and scrapped original components. If these waste materials are recycled well, not only can the problem of solid waste pollution be solved, but also a better sense of cost control is established for the production enterprises, bringing certain economic benefits. This is good for business development and even better for the environment. The following is a list of recycling methods that can be used for reference.

Building a green recycling industry chain

In the recycling of waste materials from silicon production, such as waste mortar, the industry has formed an industry based on the recycling of PEG (polyethylene glycol) and silicon carbide. But the recycling of silicon powder with a higher value is still in its infancy. Some of the companies in China that are dedicated to the development of industrial intelligent equipment and digital intelligent equipment are making great efforts to develop corresponding recycling technologies and equipment in order to achieve the commercial scale of silicon waste recycling and utilisation. Crystalline silicon produces 20%-30% of waste in the cutting process, and a production capacity of 500,000 tonnes will produce 100,000-150,000 tonnes of silicon waste. Through silicon waste recycling and utilisation equipment systems, this silicon waste can be recycled and reused to achieve a green recycling industry chain. For example, Xinyuan Technology Company and Shangrao Supply Chain Management signed a production equipment automation service contract for a 5,000 tonne per year project relating to the recycling and purification of silicon fertiliser in September last year. The equipment, excluding the cost of raw materials for silicon waste, electricity and depreciation of equipment, costs about 30,000 yuan per tonne to produce, while the price of recycled silicon is 200,000 yuan per tonne. 5,000 tonnes of silicon waste recycling project income of about 1 billion, plus the policy concessions for the first five years of the company, will create a profit of about 500 to 600 million yuan for the company. With the further improvement of scientific research, technology and equipment optimization and

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perfection, it is believed that silicon waste recycling equipment will accelerate the realization of large-scale commercialization and industrialization, and solve the problem of recycling silicon waste while enhancing economic benefits, reducing the pollution of the ecological environment and realizing green recycling and low-carbon production.

Building a recycling management system

From 2007 to 2010, China rapidly entered the industrialisation stage of photovoltaic development, and the storage capacity of photovoltaic power generation units has been rising year by year, while the service life of photovoltaic power generation plants is about 25 years. In addition to the damage caused by natural and human factors, some components will need to be eliminated and replaced from the first five years of operation. With a huge incremental market and stock market, the number of PV modules that are scrapped is also huge. However, the high cost of recycling and transportation leads to low economic efficiency. Overall, China's PV module recycling technology, still in its infancy, has not formed a mature and scalable application. See the following two areas.

1. Enhancement of PV module recycling technology. Technical enterprises (e.g., the Institute of Electrical Engineering of the Chinese Academy of Sciences) and enterprises related to the PV industry should increase their investment, continue to innovate and carry out relevant basic research, so that PV module recycling technology can be gradually improved, end-of-life PV modules can be effectively recycled and reused, and ecological pollution can be reduced as much as possible.

2. Construct a management system for the recycling of photovoltaic modules. Firstly, national attention and smarter regulation are needed. The Development and Reform Commission and the Ministry of Ecology and Environment have set up an information notification mechanism for PV project cycles, created a nationwide information network platform, increased supervision of end-of-life PV module end-processing. At the same time platform support was provided for recycling and reuse enterprises through the internet, big data and other modern communication technologies, such as information, procurement and logistics services. Secondly, for the problem of low economic benefits of recycling and reusing PV modules, financial incentives and certain tax incentives can be implemented to help PV enterprise producers optimise their designs and take the initiative to take responsibility for the pollution caused to the ecological environment in the production of the enterprise, so as to achieve the sustainable development of PV as a clean and renewable energy source. Once again, continuously improve the recycling system of PV module end-of-life, appropriately categorise PV module waste, etc. into the electronic raw material recycling management system and clarify the process of utilisation of each link. The main responsibility of the whole industry upstream, midstream and downstream links is to build a PV module recycling and recycling management system. Finally, they should develop and improve the module recycling standard system, and manage the PV industry from the perspective of laws and regulations, so that PV power generation can achieve a truly green and sustainable development.

Upgrading PV energy storage technology

PV power generation is inseparable from the power storage system. Improving PV energy storage technology helps the industry develop to a higher level. Photovoltaic power generation applications of electricity storage methods are mainly supercapacitors and batteries, as well as superconducting and flywheel energy storage. The main way is battery energy storage, currently more widely used by lead-acid batteries because of its reliable performance and high degree of modularity. However, the general life of the battery is 3-5 years, the replacement frequency is high, and improper handling will bring pollution to the local ecological environment. The state should introduce corresponding policies to guide capital investment in the research and development of terminal energy storage products, while guiding relevant battery factories to invest more research and development funds, research and development of more energy storage advantages of technology, design more efficient and environmentally friendly energy storage products, so that photovoltaic power generation and energy storage can achieve common growth of environmentally friendly green products. As China's energy storage technology has been a difficult point, scientists are still in the process of research and development. The market needs low cost, excellent quality, long life products. There are not enough new research material, so it is inconvenient to do too much analysis here.

Environmental recommendations for the construction of photovoltaic power stations

Planning from the top, building green photovoltaic power stations

From the planning, survey, environmental assessment, construction of photovoltaic power station to the completion of operation, governments around the world need to develop a perfect plan about the green power station and post-supervision protection program, including the groundwater pollution treatment, ground vegetation damage situation, the effective treatment of solid waste, the prevention of air pollution, the surrounding flora and fauna habitat, etc. They should have adequate preplanning and assessment to prevent environmental pollution accidents, but also to prevent the disturbance and destruction of the ecological living environment.

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Using intelligent environmental monitoring to guard the green operation of PV power stations

Photovoltaic power stations, the implementation of environmental monitoring systems, real-time integrated monitoring of the internal and peripheral links of the power station, its internal and external temperature, humidity, soil composition, water sources nearby, vegetation and other multifaceted factors should be considered for real-time big data analysis and comprehensive evaluation. Besides,the ecological environment around its targeted real-time control can be prepared to do prevention and management of the ecological environment around the power station. The possible adverse ecological impact during the operation of the power station is minimised.

Increase the number of environmental monitoring staff and improve the power station management system

During the operation of the photovoltaic power station, environmental protection and management should be focused on. On the one hand, a PV power station ecological environment monitoring and protection department should be set up to ensure the smooth implementation of daily environmental monitoring The surrounding ecological environment situation should be regularly monitored, and the surrounding ecological resources damage should be timely managed; On the other hand, a ecological environment monitoring system of the power station can be established. In the actual governance, through the corresponding ecological environmental protection strategy, the relevant system, the PV power station inside and outside the air pollution, ecological environment pollution and light pollution should be comprehensively prevented and controlled. Scientific and reasonable real-time monitoring of the environment inside and outside the photovoltaic power station, work on a refined management approach and real-time control and management of possible pollution should be made to ensure that the production of photovoltaic power is more energy efficient, green and environmentally friendly.

Government departments playing a policy guidance and regulatory role

The PV industry needs to continue to introduce various regulatory measures, using laws and regulations to urge enterprises and prevent pollution incidents from arising, with policy support to help the green and healthy development of the PV industry.

Relevant departments announce subsidy policies to help the healthy development of PV

At different stages of PV industry development, national policies should be prophetic first, giving enterprises and technology research and development institutions a series of subsidy benefits, including installed subsidies, feed-in tariff subsidies, and using different forms of subsidies, such as cash subsidies, tax reductions or concessions, investment rate proportional subsidies and advance payments. With the continuous expansion of the PV industry, a number of excellent PV enterprises have been cultivated, and the PV industry has gradually moved from the previous policy planning economy to a market economy. The cost of power generation has fallen to the lowest in history and can match the cost of traditional energy sources, and more regions have achieved grid parity. However, the country still needs to adopt certain financial subsidies, tax concessions, loan concessions and deferred loans and other policies to encourage breakthroughs or enhancements in the technical level of the industry, to promote scientific research institutions and enterprises to do real work. We are not afraid of policy support and capital investment traps. To achieve green development of the photovoltaic industry, more active and efficient policy changes are needed.The government and enterprises are of one mind, only then can we truly embark on the green PV road.

Raise awareness of regulations among industry personnel and strengthen substantive supervision by the government

The photovoltaic industry needs to be escorted by laws and regulations. Firstly, green development requires relevant departments (Ministry of Environmental Protection, Ministry of Industry and Commerce, Ministry of Industry and Information Technology, etc.) to play a joint supervision mechanism, multi-departmental linkage and build a platform for dialogue between enterprises and the government. Regulations should be promoted for enterprises, carrying out training for PV practitioners, implementing an assessment for personnel to pass the assessment before they can be employed, and the assessment must include content related to environmental protection. Secondly, we should improve the regulations governing the development of environmental protection in the industry, implement an extended responsibility system for producers in the PV industry, clarify the social and environmental responsibilities of enterprises involved in the PV industry chain, and institutionalise the responsibilities of all subjects. We will also develop national standards for each technology and pollution control in the PV industry, such as collection, storage and transportation, and strictly enforce the laws and regulations related to the PV industry.

Put an end to abusive policies and negligent regulation. Environmental protection departments should improve the regulations and professional quality of law enforcement officers, while the local PV industry needs to increase supervision, and the PV industry itself is a sunrise industry that benefits the country and the people. However, the implementation of policies around the different strengths leads to poor results. For example, in some regions, companies are blindly developing their industry layout in order to obtain state subsidies and financial incentives, and even investing in production without scientific planning of production equipment and production processes, placing too much emphasis on short-term benefits. They have not incorporated environmental

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protection into their business management and lack a sense of responsibility for environmental protection. In addition, the development of China's photovoltaic enterprises speed up. The product sales mainly rely on exports, and export destinations are mostly developed countries in Europe and the United States. China's photovoltaic enterprises and local governments are prone to greed for immediate economic interests, and there will not be regulatory implementation. The supply chain of the source of pollution left to the domestic, and thus increasing the cost of our environment. Therefore, what often needs to be improved is the government assessment mechanism, the implementation of policies, the improvement of the government management model, the government's ability to govern, etc. The people in power are those who understand laws and regulations, which is the first step to do a good job in supervision. Then, in the implementation of laws and regulations, better manage the development of photovoltaic industry and protect green and sustainable development.

Establishing and improving laws and regulations

For China to stand firm in PV power generation on a sustainable basis, it is not enough to rely on government policy guidance alone. In the development of the photovoltaic industry, the Renewable Energy Law implemented in 2006, has been used as the basis for factoring. After a short period of market adaptation, the law was reworked in 2009 in order to better regulate the development of the market, allowing some of the conditions that had previously hindered the development of renewable energy to be improved to some extent. However, after more than a decade, the act still has a number of shortcomings in terms of development content. And its accompanying PV development regulations are in need of improvement, such as the lack of an incentive system for the PV industry. To promote the sustainable development of the PV economy, regulations need to be continuously strengthened.

Typical case studies of the photovoltaic industry in environmental protection

Although there are still many environmental shortcomings in the photovoltaic power generation industry, The strong momentum of the development of the photovoltaic industry cannot be stopped, and the historical mission of photovoltaic power generation as an important renewable energy in the future cannot be stopped. In order to achieve China's 3060 double carbon requirements, we need to adhere to the scientific concept of ecological development and use photovoltaic to create new ecological development opportunities. The author selected several successful photovoltaic power generation projects in China for case study as following.

Large-scale distributed photovoltaic projects in urban construction

With the development of the photovoltaic industry in the last decade, industrial technology, processes and production equipment have been comprehensively upgraded. Photovoltaic power generation, mainly in the form of distributed power generation projects, is slowly developing in cities. As technology continues to innovate, it brings more green and clean energy supply. Usually, a large number of photovoltaic power generation systems are used above buildings such as large railway stations, high-speed railway stations, airports, schools and parks to achieve the large-scale and universal application of clean energy, which not only meets the daily electricity needs within the buildings, but also sells electricity to earn benefits and gets more and more organisations involved.

Photovoltaic demonstration project of railway station: Wuhan Railway Station is a PV power generation project completed in 2009, using the building roof and storm shelters for PV power generation, reducing the consumption of traditional energy power. As an important demonstration project for PV power generation in Hubei Province, it uses the building model of PV building integration, which is the largest volume and installed capacity of the province's PV project to date. Relevant data shows that the photovoltaic power generation project generates about 2.04 million kilowatt hours of electricity per year, which is equivalent to a reduction of about 2,040 tonnes of carbon dioxide emissions and about 557 tonnes of standard coal per year. The distributed and large-scale application of photovoltaic power generation projects in the city will not only bring economic benefits but will also bring environmental benefits for carbon reduction and emission reduction.

Building centralised PV power generation projects in desert areas

How to maximise the role of photovoltaic energy for ecological environmental protection, how to scientifically lay out and utilise photovoltaic energy according to local conditions, and how to enhance the proportion of photovoltaic energy consumption. These aspects should be considered. We should full use of the characteristics of desert areas, such as extensive land resources, sufficient sunshine, sparse population and lack of animal and plant resources, to apply PV power generation in a large scale and centralised manner. Practice is needed to solve the ecological landscape of the desert areas, to explore a new photovoltaic road to wealth.For example, Northwest China is a blessed place for photovoltaic. Land desertification, serious population outflow and poor natural conditions in Northwest China have always been the "pain" of China's development. China's desertification area exceeds 2.6 million square kilometers, accounting for about 30% of China's land area. Northwest China is an area to be developed and has great development potential. After years of practical experience and the establishment of exchange platforms related to sand control (such as the Kubuqi International Desert Forum), PV projects in desertification areas have achieved remarkable results and valuable practical experience, which have helped China to reduce the desertification process.

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China's No.1 photovoltaic project - Qinghai Tala Tan photovoltaic power station - is located in Tala Tan in Qinghai province, where was once a semi-deserted grassland turning into an important demonstration project for the photovoltaic industry. It covers an area of 609 square kilometres, being close to the size of a Singapore. Not only has the pastoral industry been developed and the ecology restored, but it has also led to economic development. The annual power generation reaches more than 9 billion KW/H, which is equivalent to saving 2.7 million tonnes of standard coal consumption and reducing CO2 emissions by about 9 million tonnes per year. At the same time, due to the management needs of the power station, thousands of jobs are brought to the local area. With the sand receding and greening into the project, it drives the development of local agriculture and animal husbandry, developing photovoltaic sheep, photovoltaic crops (Cistanches, Chinese wolfberries, licorice, etc.) , which not only solves the risk of fire after the grass grows high, but also makes full use of the space under the board, driving local farmers to develop breeding and planting, and achieving well-off and wealthy. The electricity is not only used for the local power grid, but also can be transported to Jiangsu, Henan and other power grid systems, realising the clean use of photovoltaic power generation, reducing the consumption of highly polluting traditional energy sources and promoting energy restructuring. The success of sand control and sand management in combination with photovoltaic power generation projects has also led to a thorough improvement of the ecological environment.

Concentrated photovoltaic power generation projects have blossomed in desertification areas, setting up one green photovoltaic power station after another, with sand receding and greening, adding many carbon sink forests and grasslands, thus improving the ecological environment.

Future Outlook of the PV Industry in Environmental Protection

The various stages that our photovoltaic industry has gone through in the past have been the cornerstones of its future sound development. Global climate change is becoming more and more dramatic, posing urgent challenges to the future of the world's energy sources. Coupled with the global outbreak of epidemics in recent years, this has put the world on pause, and people are forced to think about the optimal solution for man and the environment to live in harmony. The future energy mix will be redefined, with new or renewable energy sources gradually expanding their share, as shown in (Figure 6).

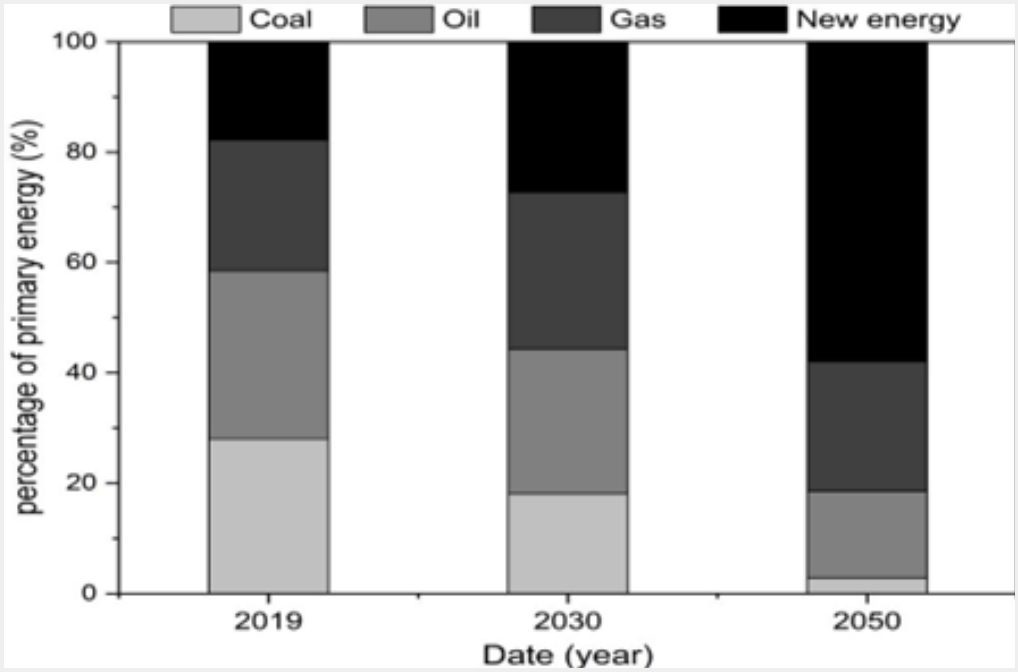

Figure 6: Future energy development in China.

The development of photovoltaics has become one of the most important initiatives to solve environmental problems. in May 2022, the state issued the Implementation Plan on Promoting the High Quality Development of New Energy in the New Era, proposing that in 30 years, the total installed power generation capacity of these two types of re-energy sources in China will reach more than 1.2 billion kW. A global institution has estimated that in 60 years, the total installed capacity of photovoltaic power generation in China will account for 40% of the total landscape new energy, which is about 26 times the growth space compared with the current relevant data, and the required land area is 45,000 square kilometres. It can be said that both domestic policy

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guidance, or international prediction of China's photovoltaic development, have shown that China's photovoltaic industry has a more positive and important role in environmental protection. It is believed that PV will have greater opportunities for future development under China's "double carbon" target.

Future technologies for green PV development

To be able to promote the rapid development of the economy in the future, as well as drive the environment to be better protected. The core factor of the photovoltaic industry is that technology can continue to break through and progress. As the largest and most comprehensive PV industry chain in China, its every link needs technological progress to upgrade. In the future, there is hope that technological advances will solve or balance the environmental pollution problems that exist in the manufacturing and operational aspects, and that technology will allow PV to make more contributions to environmental protection.

Technological advances to promote the green development of PV equipment and accessories

Example: Chinese patent technology of polyolefin photovoltaic backsheet technology use. As the most basic component of photovoltaic power generation, the back of the battery component is the outermost layer of the photovoltaic backsheet, whose function is to protect the photovoltaic cells. However, we all know that the service life of PV cells is at least 25-30 years, so we need PV backsheets to achieve the same service life as PV cells in order to be the most environmentally friendly and cost saving. However, PV backsheets are currently made up of a basic layer, a protection layer and an adhesive layer. The basic layer contains PET, which has been used for around 30 years in practice. However, the PET material is prone to cracking, delamination and deterioration of the adhesion conditions over time, which in turn does not provide a stable protection for the battery. In addition, the protective layer contains a fluorine film, which is difficult to degrade and recycle, and it is easy to cause pollution to the environment. In order to solve this problem, our scientists have delved into the field of photovoltaic backsheet research and have been making breakthroughs in polyolefin materials since 2009, applying for a number of patented technologies. Polyolefin materials are more barrier, protective and environmentally friendly and reusable than previous materials, so the industry is gradually trying to replace PET and fluorine films with polyolefin materials. This is why the industry is gradually trying to replace PET and fluorine films with polyolefin materials, in order to obtain a more environmentally friendly PV backsheet, as well as to improve the poor performance of the original backsheet and to change the solar module and extend its service life. It is an important application direction at present and in the future. China is now already a large sales country for photovoltaic formation. In actual use, fluorine backsheet is still a mainstream. However, Europe, the United States and Japan and other countries containing fluorine backsheet retention are greater. For this reason, China can also continue to make breakthrough in technology, according to different stock market, research and development of different new materials and new products, in order to replace the global original use of low environmental performance of the product. It will have market prospects and more environmental significance.

Technology to promote photovoltaic hydrogen production, helping the industry to find a new green development growth pole

In recent years, the development of China's photovoltaic industry has been in an unstable situation due to factors such as the rise in upstream raw materials, the price fluctuations of silicon, and the decline in demand for photovoltaic materials caused by overseas epidemics. At the other end of the spectrum, hydrogen is still mainly made from fossil fuels such as oil and natural gas, which cannot be adapted to the times. As a result, a double-needed path was formed, in which PV companies made hydrogen to seek new growth and the original hydrogen production companies turned to use PV to save themselves. The development of the photovoltaic industry and the green market for hydrogen production have led to the development of photovoltaic hydrogen production under the conditions of existing technology. Over the years, researchers have researched the production of green hydrogen energy from photovoltaics through electrolytic water production units. This technology is now developing faster abroad and is gradually maturing in China. Compared to other conventional hydrogen production technologies, some scholars have researched photovoltaic power generation for hydrogen supply, which is more continuous and reliable, with a progressively lower relative cost and zero carbon emissions in the hydrogen production process. The market application of PV hydrogen production technology has also been put on the development agenda. In March 2021, PV industry Longi, as the largest PV enterprise in China, started to enter the PV hydrogen production business, followed by the head enterprises in the industry such as Xiexin New Energy, Sunshine Power and Jinko Power, which have responded by building up all aspects of hydrogen production technology, operation management and industry chain cooperation. Among them, the alkaline water electrolyzer built by LONGi in Wuxi, Jiangsu Province, has a single hydrogen preparation capacity of 1000Nm/h. Through the technology, we are actively building up the industrialisation of photovoltaics and hydrogen production. Of course, the industry is still in continuous development and the future market demand is high. Compared to traditional fossil energy hydrogen production, photovoltaic hydrogen production effectively reduces the previous consumption of fossil energy, reduces the emission of carbon dioxide and other by-product pollutants, and achieves a multi-effective linkage among the coal and chemical industries, the petrochemical industry, the renewable energy industry and the new fuel cell industry in the environmental protection business.

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Smarter and more convenient grid-connected photovoltaic module technology as a future trend

Unlike other re-energy power generation, photovoltaic power generation has more space for regional use. So such a wide use of space on the intelligent operation of photovoltaic power generation components is convenient installation providing higher requirements. Some scholars say that traditional solar module systems cannot take into account each module in series and parallel because of the power problem, which means that it is difficult to make individual modules operate in an optimal way under normal working conditions, thus affecting the efficiency of the power generation system. This makes power generation more modular, systematic and simple, which in turn makes it possible to build PV power stations quickly and improve the stability and efficiency of the system. At the same time, research into the power management system of smart PV modules has shown the use of new data analysis and processing methods to achieve flexibility in algorithms and powerful processing capabilities. The use of advanced design concepts to integrate intelligent photovoltaic modules into the internal intelligent power management system allows the PV power generation system to achieve power management mode component level, and provides a better basis for research state with monitoring systems to implement monitoring of each module. In this way, intelligent inspection of individual modules can better improve the reliability and safety of PV power generation in system operation. This will improve the reliability and safety of the system. Of course, in the future there will be more and more new technologies such as the Internet of Things wireless sensor technology. Through the empowerment of these technologies to sense the outside world of photovoltaic power generation, a sensor network mode of measurement and control network are bulit in such a sensor network measurement and control platform to establish intelligent monitoring and auxiliary control systems. These measures aim to achieve the operation and management of photovoltaic power plants under intelligent monitoring state, achieve intelligent monitoring, intelligent management, intelligent judgement, etc. In short, with the continuous construction of distributed photovoltaic projects in China, the power supply provided by those who make electricity online in terms of technology, safety risks, monitoring, metering, control, etc. will face a variety of complex conditions, so that the latest photovoltaic power generation system and its components need to be more intelligent and convenient. In the future, intelligent and fast photovoltaic industrial systems are indeed, and their popularity can make a continuous green energy contribution to the cause of environmental protection in China.

Diversified and integrated development of the photovoltaic industry

The future energy structure will tend to be networked, what is "energy networking"? What does "energy networking" mean? It means building up a network system that allows multiple energy sources to complement each other. As we are now vigorously pursuing the "double carbon" goal, the proportion of "non-carbon energy" in the future is bound to increase strategic significance. PV power supply, oil and gas power supply, hydrogen power supply and new energy storage systems will form an integrated development model, which will push the PV industry from high-speed development to high-quality development. The future of the photovoltaic industry will continue to intensify the elimination of the fittest, and green environmental protection is the theme of development. With the gradual decline in PV costs in China in recent years, most places have achieved grid-parity PV energy supply. The next market development trend will be to diversify and integrate the transformation, giving greater added value to each product in the PV industry chain. Some foreign voices have said that they want to overtake the Chinese PV industry through PV diversification in 2011. This has also stimulated innovation in models and technologies in integrated building integration, fisheries and light complementarity, agriculture and light complementarity, etc. in China. Models such as aircraft or car integrated PV have become the new direction of development.

Being different from the previous BAPV (photovoltaic system attached to the roof) model, BIPV currently has two forms of expression: the combination with the building and the integration with the building. Some scholars predict a widespread explosion in the industrial use of BIPV starting in 2023. The emergence of BIPV was made possible by two documents, the Notice on the Submission of Pilot Schemes for Distributed Rooftop PV Development in Whole Counties (Cities and Districts) and the Technical Regulations for Roofing with PV Modules, which came into effect in January this year. This marks the opening of the prelude to the integration of rooftop photovoltaic buildings in China, but also accelerate the process of transformation of China's energy structure and lead the high-quality development of the photovoltaic industry. Now through a high level of building mode, an energy-consuming building can be transformed into an energy-saving building, and then into a capacity of the building, which is BIPV. It is based on the standard of China's distributed photovoltaic utilization and development of the technical basis, and China's roof photovoltaic installation technology progress, quality standards and capacity iterative upgrade of the industry development status. At present, almost all key PV enterprises are laying out the development of BIPV, such as Longji's "Longding" and Trina's "Tianneng tile". In the future, there will be a richer variety of PV buildings and more diversified ways to create green energy. Large enterprises with technology, pattern and knowledge of environmental protection will be more and more suitable for the needs of the new period and develop better, while other enterprises with insufficient capacity and lack of strategic vision will inevitably usher in a major reshuffle of the industry, and the elimination of the fittest is inevitable. By promoting the integration of photovoltaic buildings, the photovoltaic industry has blazed a new path in energy conservation and emission reduction in terms of environmental protection and green ecology.

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The future development of the PV industry and energy storage trend

At present, the cost of photovoltaic power generation in China is already the lowest in history and can already compete with conventional energy sources with more advantages. The most important disadvantage is that the energy supply is unstable, and the next step in the whole industry chain needs to be solved is the problem of high-quality low-cost energy storage, which sends out solar energy, reserves it, stabilizes it and then supplies it out. Once the energy storage problem is solved, the energy transmission of the whole chain will not be a problem. At present, China's energy storage situation is still in the process of continuous development, and so far has not yet fully found a good way to store energy with high technology and low equipment cost. As mentioned above, photovoltaic power generation has different sunlight and different energy supply. At the present stage of the large-scale development of photovoltaic power generation in China, if a high proportion of power enters the power grid, the grid system will be "unable to eat, can not catch". High safety and energy-efficient storage methods are needed to balance supply and demand, to maximise the potential of energy storage, to connect "generation, transmission, storage, distribution and use", to share light and storage, and to promote the long-term high-quality development of PV. In July 2011, the "Guidance on accelerating the development of new energy storage" was issued, stating that in 25 years, China will achieve from the initial stage of commercialisation of new energy storage to the stage of large-scale development. What's more, energy storage equipment should have a high safety factor, low cost of use, reliable performance and long life. New energy storage equipment needs to be fully marketed in 30 years, which is the strategic goal. The equipment should be fully marketable. For example, on 11 April 2021, the world's first photovoltaic plus energy storage, outdoor demonstration experimental platform under the responsibility of the State Power Investment Corporation broke ground for construction. Its construction can promote the solution of China's PV plus energy storage technology through the PV and energy storage, together with the development of the rapid and accurate storage of electricity, so that the short-term fluctuations of PV power supply can be balanced. These measures are made to ensure the maximum load power to be curbed, reduce the emergence of supply-side peaks, contribute to the stability of electricity prices, reduce the cost of future transmission network upgrades and capacity expansions. In any case, energy storage is a core issue that needs to be addressed as soon as possible, and a comprehensive solution to the energy storage problem will allow PV to move more steadily and better in terms of environmental protection.

The future of the photovoltaic industry will be green by taking advantage of its geographical location

Northwest China and other regions have abundant sunshine, long sunshine hours, strong penetration of light, and flat geographical advantages. There are also deserts, grasslands, saline alkali lands, old abandoned industrial and mining areas and uninhabited wasteland. The development of large-scale centralized photovoltaic power plants has geographical advantages. Taking Shaanxi for example, the local Yulin City completed centralized grid-connected commercial photovoltaic power generation projects amounting to 6.25 million kilowatts. There are 116 power stations in the Mawusu Sands alone, amounting to 6,152,000 KW, which have also attracted overseas media attention. The ecosystems in these areas are fragile and unsuitable for human life. Building large scale photovoltaic power stations is a way to revitalise the stock of land and ecological resources according to local conditions. Making full use of the value of ecological resources and turning disadvantages into advantages is the future trend of green development in China's domestic PV industry. Through photovoltaic power generation projects, technology and talent are driven deep into these unfavourable production and living places. Playing the subjective initiative and transformative wisdom of people, actively implementing green strategies, ecological development and environmental protection strategies, making every effort to balance the conflict between sustainable development and ecology, helping to enrich the local area and finding a new ecological balance while allowing PV to generate clean energy, and awakening the original vitality of ecology, are the future trends of China's development.

The northern regions of China are suitable for the development of the photovoltaic power industry, which can improve the local economic situation and guarantee a green energy supply, as well as taking on the responsibility of building an ecological civilisation and protecting environmental biodiversity. Photovoltaic power supply gives wings to regional poverty eradication and opens up new ideas for the green take-off of the local economy. Combined with the local ecological and environmental conditions, a scientific and quantitative assessment is made to find out the punch-out syndrome between industrial development and ecological environment, so as to achieve a more comprehensive and safer sustainable operation of the photovoltaic industry in the local area.

Future cross-industry complementarity to promote the green development of the photovoltaic industry

The photovoltaic industry itself has the advantage of environmental protection and energy saving, and in the future it can be combined with the pollution industry across industries to complement each other's strengths and achieve a balanced and far-reaching effect. In the future, the photovoltaic industry will continue to drive other industries together to bear the fruits of environmental protection. The following are examples from two areas to illustrate the form of cross-industry complementarity.

PV and wastewater treatment plants complement each other as a new trend

In China, the average electricity consumption is 0.292 KWh/m3. If the daily treatment capacity of the national sewage

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treatment plants is 16.573 million cubic meters, it will cost about 48.39 million kilowatt hours of electricity to treat sewage every day, which is equivalent to the daily power generation of Gezhouba hydropower station. The annual electricity consumption is 13.318 billion KWh, accounting for about 0.2% of the total electricity consumption of society. Electricity consumption and high operating costs reduce the investment benefits of sewage treatment plants, and even become a bottleneck in the normal operation of some sewage treatment plants. As the problem of energy shortage and environmental pollution is becoming increasingly serious, energy saving and consumption reduction have become an urgent to address the realities of the sewage treatment industry. Therefore, the "photovoltaic plus sewage plant" model will be widely invoked in the future. The biological ponds of wastewater treatment plants occupy a large area and are left unused, so if photovoltaic modules are set up over the biological ponds, the space resources can be used effectively without taking up land area. And photovoltaic power generation system can not only effectively reduce the operating costs of the sewage plant, to provide green power energy for the plant, but also to better protect the environment, to contribute to energy saving and environmental protection. It is simply a win-win situation.

Generally speaking, sewage treatment plants occupy a large area, relatively few buildings around, few high-rise buildings, and the pools and roofs of sewage treatment plants have a large area and good building quality, which is very conducive to the installation and efficient use of photovoltaic modules.It can be based on the different classifications of the integrated biochemical pond, by adding a roof at the end of the wastewater treatment process - the top of the clarifier, to reduce the wind speed above the pool, improve the local small environment, reduce the evaporation of pool water, improve the temperature of the pool water, and increase the return on sewage treatment. Secondly, the land of the sewage treatment plant is generally administratively allocated, and the land use life is in principle infinitely long. Compared to other urban building roof development distributed photovoltaic power generation, investment stability is good. Most importantly, the sewage treatment plant electrical energy consumption is large, on 24-hour non-stop operation. Photovoltaic power generation in the daytime peak load period using the "self-generation and self-consumption" approach. The power load of the photovoltaic power station is directly borne by the sewage treatment plant, on the one hand, to reduce the impact on the quality of electricity in the grid when the business disputes with the power operating company. On the other hand, it can make full use of the national policy subsidies for new energy distributed power generation and reduce the cost of electricity. Therefore, the use of PV distributed power generation has a high-power generation efficiency and can seek preferential subsidies from the government in terms of policy, and can also achieve the environmental benefits of zero emissions and improve the image of the enterprise in taking social responsibility.

PV and urban construction complement each other as a new trend

With the double carbon target, all kinds of PV projects are competing to help add to the energy saving and environmental protection of cities to reduce carbon. The application of PV is becoming more and more widespread, turning energy saving into creating energy, which is becoming part of modern life. Examples include photovoltaic seating, photovoltaic factories, shopping mall roofs, villa roofs and photovoltaic street lights, billboards and carports. Photovoltaic seating in urban public space is an indispensable facility, mainly to provide a comfortable play space for the public. With the gradual improvement of people's living standards, the quality of life has gradually become an important value choice, and comfort has also become one of the evaluation standards.

The photovoltaic seat applies solar power generation to the leisure seat, which means that the comfort of the seat is enhanced and the urban environment is beautified; solar power generation is used as the electricity supply and the seat is equipped with a USB port to provide convenient charging services.

The night photovoltaic lighting is shown in..., using a high luminous efficiency light source lighting design, time control plus light control. The effect shows high brightness and quick installation. There is no need to lay cables, no consumption of traditional energy, long service life and so on. The society actively advocate the use of green energy products, and emphasise the art lamp landscape and scenic surroundings, historical and cultural harmony. It is commonly used in industrial parks, squares, parks, pedestrian streets and other places for night lighting and landscape illumination.

The photovoltaic sunflower is the shape of a sunflower petal, visually giving a beautiful high value, and is also referred to as the photovoltaic sunflower. Space is efficiently used in order to install photovoltaic power generation systems. It is one of the ecological and technological landscapes with environmental characteristics in modern parks, scenic spots and agricultural sightseeing parks. It is a highly intelligent combination of power generation, energy storage, environmental protection, aesthetics and technology, and is also used in parks, photovoltaic gardens and agricultural tourism parks. Each "photovoltaic flower" has a single installed capacity of 2600W, and with the energy storage system, it can provide sustainable green power energy for the surrounding landscape equipment during the day, and can also supply power to itself and the surrounding equipment at night through the configured energy storage system.

The photovoltaic advertising bin, is a clever combination of advertising media and a bin, which consists of a solar panel, a separate waste collection bin and an advertising light box. The sorting bin can prompt visitors or the public to sort and put it away to achieve the purpose of recycling waste materials.

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Photovoltaic advertising light boxes can generally be used as a means of promoting commercial advertising or public service advertising, achieving the dual communication effect of public service promotion and economic benefits. By collecting solar energy and converting it into electrical energy, the solar photovoltaic panel can provide electrical energy for the light box lighting system at night, which can reduce energy consumption and can be used for 3 to 5 days of lighting. As a new scenario product using solar power generation, it has solved the installation and safety problems of outdoor light box power wiring, and has also reduced power supply for environmental protection and energy conservation construction of the city, which will add a new street view to the future city.

The photovoltaic carport is a simple and easy-to-use application scenario that combines a building with photovoltaics. Making full use of existing sites, it is cost effective and quick to install, and has become increasingly popular in recent years. Placing the PV module on top of the carport generates electricity and also provides protection from rain and sun. Such carports using photovoltaic power generation can be equipped with energy storage. After the installation of charging piles for new energy vehicle charging, the surplus electricity can also be grid-connected to make money [1-40].

Summary and Outlook of this Paper

Conclusion

The photovoltaic industry is the most advantageous renewable energy source in the future due to its ability to generate clean energy, large resource storage capacity, and environmental friendliness and greenness. This paper starts with an analysis of the current situation and development of the renewable energy and photovoltaic industry, and then begins with a study of the key issues of environmental pollution that have often been criticised in the photovoltaic industry chain over the years. In addition, improvement measures and suggestions for the pollution and management research situation are proposed, and finally a predictive analysis of the future development trend of the photovoltaic industry is made. The main conclusions are as follows.

Firstly, photovoltaic power generation has great positive significance for environmental protection, and the development of the photovoltaic industry allows the environment to be improved, and the future is promising.

Secondly, in the development of the photovoltaic industry, we need to take a comprehensive, objective and scientific view of its positive role in environmental protection, reflect on the pollution problems in the industry chain, and improve the strengths and weaknesses of the positive solutions. Environmental protection requires the PV industry to be guided by scientific policies, a reasonable regional layout, and an orderly and coordinated development according to local conditions.

Thirdly, the management of the PV industry needs to be more sophisticated, and the focus of management needs to be on environmental protection, pollution prevention and the construction of management teams.

At last, greater efforts can be made in the future by relying on new technological breakthroughs in the PV industry, supervision and management, and long-term regional planning in terms of environmental protection.

Outlook

The future of the PV industry in terms of environmental protection can also be explored in depth in the following places.

First, photovoltaic power generation is a process that relies on the light of the sky to supply energy, which makes it impossible for photovoltaic facilities to continue to play their role in environmental protection in an environment where there is not enough light. And their effectiveness in environmental protection needs to be improved. In other words, it is worth studying the new idea of "making good use of existing equipment and creating colourful environmental protection values".

Second, photovoltaic power generation requires energy storage. The energy storage technology has not been effective broken through. Making a deep breakthrough in energy storage and solving long-distance transmission across regions and countries has great historical and strategic significance for protecting the ecological environment and is worth becoming a research hotspot in the future.

Third, crystalline silicon, the core raw material of photovoltaic panels, has a far-reaching impact on environmental pollution. In the future, scientists can make research in new materials and explore more environmentally friendly and green raw materials to replace them, which can become a new direction for environmental research.

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