

# Comparative Analysis of the Photovoltaic Industry in China and the US: Policy, Innovation, and Market Competitiveness

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**Abstract.** The photovoltaic (PV) industries of China and the United States have evolved in distinctively different ways, driven by vastly contrasting government policies, technological innovations, and market dynamics. Over the period from 2015 to 2024, the Global Price of Energy Index witnessed a significant surge of 42%, bringing the urgency for viable renewable energy solutions to the forefront. China's PV industry, underpinned by robust government support and substantial investments, has soared to global prominence through its large-scale manufacturing capabilities and efficient production processes. In stark contrast, the U.S. PV industry places a greater emphasis on pioneering technological advancements in advanced PV technologies, yet it still relies heavily on imports to meet domestic demand. By analyzing data sourced from the International Energy Agency and industry-specific reports, this comparative analysis illuminates how these fundamental differences will mold the future competitiveness of both nations within the PV sector and profoundly influence the trajectory of the global energy transition.

**Keywords:** Solar photovoltaics; clean energy; China; United States; innovation.

## 1. Introduction

The energy index of global price climbed approximately 42% during from 2015 to 2024 [1]. Extreme weather varies equally dramatically, with the global average peak temperature in 2023 growing by 18.89% in relative to the growth in 2015 [2]. Furthermore, the loss of billions of dollars from natural disasters and extreme weather aggravate year after year [2]. People need economical, stable, long-term renewable energy to avoid the energy price crisis and serious loses of extreme weather. The energy cost of photovoltaic solar energy is ranged from \$0.50~ \$1.50 per watt-hour, which makes PV a very economic answer to global climate change and the energy price crisis [3]. As a leader of PV in the world, China and the United States maintain the technology development and market expansion [3].

Solar photovoltaics (PV) is one of the forefront technologies in the global energy transition and in achieving climate targets. The global installed solar PV capacity grew at a record pace in the recent decade, led by costs reductions [4]. In the pursuit of net-zero emissions, the rapid expansion of solar PV should continue. In 2023, solar PV made up for 75 per cent of the new renewable energy capacity added worldwide, owing to low costs and policy interventions, increasing by 23 per cent the largest growth of any renewable energy source [5]. China, the U.S., the EU, and India are expected to drive further expansion due to favorable policies and economic factors.

China is the global leader in solar manufacturing, commanding over 80% of the market [4]. With the government actively promoting the development of the PV industry through a series of policy measures, China not only raised the technical standards of the industry but also promoted the expansion of domestic and foreign markets [6,7] In contrast, the U.S. has been trying to catch up in recent years due to the pressures of the environment and economy. Despite its significant progress

with a record 11 GW of new capacity in early 2024, it only meets a third of domestic demand, compared to China's overwhelming global dominance [8-10]

The central research question of this paper is: what are the major differences between China and the U.S. in terms of the current state of development of the photovoltaic (PV) industry, and what are the implications of these differences for the competitive position of the two countries in the global PV market? To explore this question in depth, this paper compares the development status of the PV industry in China and the U.S., focusing on the development status of leading companies in both countries. By analyzing the significant differences between the two countries in terms of government financial and policy support, technological innovation, market applications, and development prospects, this paper will try to find out the relative leading positions of China and the United States in the global PV industry but also discover the far-reaching impact of these differences on future market competitiveness.

## **2. Policy and Goal**

### **2.1. Policy in China**

The Chinese government's five-year plan published in 2021 clearly states the importance of the development of the new energy industry. The latest five-year plan states that by 2025, the proportion of non-fossil energy consumption will increase to 20% and the proportion of non-fossil energy generation will reach 39% [11]. The photovoltaic industry is the most important part of achieving this goal. On this basis, the central government and local governments implement different policies to promote the development of the photovoltaic industry.

For subsidies, taking Shanghai in 2023 as an example, the approved subsidy standard for photovoltaic power generation projects will reward 0.1 yuan/KWH while the photovoltaic and building integration project will reward 0.3 yuan/KWH [12]. In terms of the tax credit, the State Administration of Taxation issued and implemented a two-year policy of exempting 50% of the value-added tax on photovoltaic power generation in 2016, which was changed to exempting five taxes, including the National Central Water Conservancy project construction fund after 2018 [13]. Thanks to a few policies, as of the end of June 2024, the installed capacity of photovoltaic power generation in the country reached 713 million kilowatts, an increase of 52%, of which centralized photovoltaic 403 million kilowatts, distributed photovoltaic 310 million kilowatts (National Energy Administration, 2024), rapid development. Thanks to several policies, as of the end of June 2024, the installed capacity of photovoltaic power generation in the country has developed rapidly, reaching 713 million kilowatts, with an annual growth rate of 52% [14].

### **2.2. Policy in the United States**

The United States is an important global photovoltaic demand market. Internally, the US government has promoted the development of the photovoltaic industry through a large amount of financial support, attracting investment and improving industrial competitiveness. For example, the Inflation Reduction Act [15], the largest climate bill in history, passed in 2022, increased the duration and proportion of the photovoltaic industry's ITC tax credit while increasing the tax credit on the manufacturing side. The bill calls for a 10-year extension of the 30 percent investment tax credit for the solar industry, gradually decreasing to 26 percent by 2033 and 22 percent by 2034. Besides, the Biden-Harris Administration Announces \$7 Billion in Solar for All Grants to Deliver Residential Solar to Millions of Low-Income Households [16]. Externally, to pursue energy independence and security, trade protection measures are carried out in the field of the new energy industry. In February 2018, the Trump administration implemented Tariff 201, a 30% tariff on imported solar modules [17], aimed at protecting the local PV manufacturing industry and balancing the supply and demand dynamics of the local market. During the period, for the economic conditions of local enterprises, 201 tariff policies were changed several times under the adjustment of different governments. As of

August 2024, photovoltaic cells and modules are taxed at 14.25% and enjoy an exemption quota of 12.5 GW per year.

### **2.3. Comparison of the Policy and its Application**

China and the United States have adopted different support policies for the development of the PV industry, mainly due to the large differences in the PV industries of the two countries.

China's relevant policies are based on a five-year plan that declares the development goals the PV industry should achieve within a few years. Then, local government subsidies and tax incentives help companies expand and improve their international competitiveness. The Chinese government's sizable financial investment and preferential policies have mainly contributed to the extremely high market share of Chinese PV companies, making China's PV module manufacturing costs the lowest globally. In crystalline silicon PV, China is a leader in both capacity and technology. However, due to the lack of policy support for thin-film PV technology research and development, China does not have a cost advantage, which may pose challenges for the future development of some Chinese PV companies.

In another hand, there are also some problems in China's policy implementation. Firstly, the accumulation of primitive research is insufficient, and some cutting-edge technologies lag Western countries, which means that if industrial disruptive technologies emerge, it may bring a heavy blow to China's photovoltaic industry. In addition, China's policy objectives may lack foresight, leading to possible changes in policy objectives and instability, which is not conducive to the investment and overall development of the photovoltaic industry.

Meanwhile, the U.S. PV industry chain may be more complete and rely on imports. The Chinese government provides financial subsidies and policy support for the PV industry, stabilizing its dominant position in the global market. The U.S. has also introduced subsidies and policy support but with less intensity than China. But at the same time, the U.S. government has also introduced some trade protection policies and promoted technology research and development policies. The U.S. government aims to use tariffs to limit imports of Chinese-made solar modules to eliminate what it sees as unfair competition. Although the U.S. local PV production capacity in the short term cannot meet the U.S. strong demand for photovoltaic products, a series of policies show the U.S. government's attention.

## **3. Comparative analysis of the leading industries of China and the US photovoltaic industry**

### **3.1. China and its Leading Companies**

As the world's leading renewable energy market and equipment manufacturer, China's photovoltaic (PV) technology has gradually taken shape, gaining possession of a dominant position on a global scale. By the first half of 2024, China's total installed PV capacity was 713 GW, with centralized PV power stations making up 403 GW and distributed PV installations accounting for 310 GW [18]. In China, which has the most complete PV industry chain globally, polysilicon, silicon wafers, cells, and modules all had their unity in 2022: 827,000 tons of polysilicon. 357 GW of silicon wafer; 318 GW cell and 288.7 GW module volume with increases on-year greater than 55% [19].

Some companies within China's PV industry have utilized technological advances and capacity strengths to carve out important positions in the global market, particularly in developing Topcon technology. These companies have led the industry's change to N-type cell technology and maintained a hold on the market thanks to economies of scale and efficiency gains. Jinko Solar conducted early research on Topcon technology, and its cell production capacity for Topcon cells is over 70 GW. JA Solar is an integrated high-quality enterprise that enjoys strong profitability. By the end of 2023, JA Solar's Topcon cell capacity was planned to reach 57 GW. Trina Solar has enhanced its competitiveness in the PV market by continually increasing the percentage of N-type cells and fine-

tuning its silicon wafer production capacity. By the end of 2023, Trina Solar's capacities for silicon wafers, cells, and modules were expected to reach 50 GW, 75 GW, and 95 GW, respectively. By taking the upper road on silicon material production costs and using integrated production facilities, Tongwei has established itself as a leading company in the industry. With a continuous lead in high-purity polysilicon production, the company supplies its cell and module business. It maintains an edge in technology and market competitiveness for both TOPCon and HJT technologies. This development gives the PV technology industry new vitality and upgrades entire industries. It also furnishes crucial support for global energy transitions, clearly marking China's PV industry's important position and influence in the global renewable energy sector [20].

### 3.2. United States and its Leading Companies

The development of modern solar power in the United States dates to 1954. Since then, solar power has become an increasingly important resource for the United States, making it the world's second-largest consumer of solar power. According to the Energy Information Administration (EIA), the United States installed 161 GW of utility-wide PV power and 74 GW of distributed PV power in 2023 [21]. The US solar industry remains heavily dependent on foreign resources, especially in upstream sectors still in development. The industrial chain focuses on downstream activities, such as component production and PV installations. Most of the raw materials are imported from Southeast Asia. This dependence is largely due to the relocation policy of the United States, which has led to an interruption in imports of raw materials and a slowdown in demand. The United States has a solar module capacity of more than 68 GW in March 2023. The total capacity of the solar module installations in operation is 11.4 GW, and a further 15.1 GW is under construction. Nationally, the announced solar module manufacturing capacity reached 40.9 GW (Source: U.S. Solar Manufacturing Pipeline by Component and Stage) [22].

Among the PV solar panels produced in the United States, First Solar, Qcells, Silfab, Jinko Solar, and Mission Solar are the five leading companies. Although Qcells, Silfab, and Jinko have production facilities and active operations, they are foreign companies. Qcells is a subsidiary of South Korea's Hanwha Solutions, Silfab is headquartered in Ontario, Canada, and Jinko is a company based in Shanghai, China. While these companies have increased their presence in the U.S. market by establishing production bases and expanding their presence in the market, their roots and primary operations remain abroad.

First Solar is the largest manufacturer of Solar modules in the United States, with a current capacity of 2.4 GW. It focuses on producing CdTe thin films on a utility-scale. The company is known for recycling used products and exceeding orders by more than ten times its annual production capacity. Moreover, First Solar is expanding its presence in Ohio, while also building a new plant in Alabama.

Qcells is a subsidiary of Hanwha Solutions, founded in 1999 and based in California. The company supplies the largest number of residential solar panels in the United States and owns a 1.7 GW solar panel plant in Dalton, Georgia. Qcells is also investing \$2.5 billion in expanding its business to create a complete solar home supply chain. Headquartered in Ontario, Silfab Solar has more employees in the United States and produces Solar panels at two plants in Washington, with a total capacity of 0.8 GW. In 2023, the company will launch the Elite series of solar panels and plans to build a new plant in South Carolina to produce its solar cells. Jinko Solar operates a 0.4 GW solar panel manufacturing plant in Jacksonville, Florida, serving the U.S. market. Although expansion plans have not yet been announced, the company may be inspired by LONGi's plans to build a plant in Ohio. Since 2014, Mission Solar has been producing solar panels in San Antonio, Texas, with a capacity of 0.3 GW per year, and plans to expand to 1 GW by 2024. The company uses P-type monocrystalline PERC solar cells for its products, but efficiency has not yet reached the level of its competitors [23].

Although local production of PV panels in the United States is insufficient compared to China, it remains the world's second-largest solar power consumer, with comparable market potential. Backed by a series of U.S. government policies, in addition to First Solar, Qcells, LONGi, and Silfab mentioned above, several Solar companies have announced plans to expand or build new plants in

the United States. Companies such as REC Silicon, JA Solar, and Hounen have also announced the creation of large manufacturing facilities in the United States.

### **3.3. Policy Impact on Leading Companies' Innovation and Market Competition**

China and the U.S. have taken different policy approaches to the photovoltaic (PV) industry, leading to very different results in terms of company leadership and production in the two countries. The Chinese government has provided strong financial support through direct subsidies, tax breaks and investments throughout the PV supply chain, including polysilicon, wafers, cells and modules. This has enabled Chinese companies such as JinkoSolar, JA Solar and Trina Solar to dominate the global market through economies of scale and advanced technologies such as Topcon and N-Type cells. In contrast, U.S. policy has focused on financial incentives, such as the Inflation Reduction Act (2022), which extended the 30 percent investment tax credit (ITC) for solar projects, and grants such as Solar for All. However, U.S. production relies heavily on foreign imports, and protectionist tariffs like the Tariff Act of 201 are designed to protect domestic manufacturers but limit local capacity. Companies like First Solar are leaders in thin-film technology, but the U.S. lags well behind China in crystalline silicon PV production. Overall, China's full support establishes global dominance, while U.S. policies promote local innovation but struggle to compete with China's scale and integration.

## **4. Outlook and Discussion**

### **4.1. Outlook**

China plans to add another 500 GW of solar module manufacturing capacity in the coming years, far outstripping plans for new capacity in other countries [24]. Expansion on this scale means it is likely to maintain its 80% share of the global total and remain the primary exporter of solar modules by some distance [3]. The paper can draw a reliable outlook that China's photovoltaic industry has a high market share in the global market, and under the circumstances of policy subsidies and low labor costs, many photovoltaic modules can be exported to the United States and the European Union at a low price, rapidly occupying market share. The Chinese government plans a massive amount of investment to fund the photovoltaic industry in the future [25], as well as the gradual weakening of the trade protection policy of the US government, which indicates that the competitiveness of China's photovoltaic industry may become increasingly prominent, occupy more market shares, and achieve the industry development goals planned in the policy.

However, there are also some worrying aspects to the future development of China's photovoltaic industry. The photovoltaic industry is developing rapidly, but some technologies in China's photovoltaic industry are not dominant compared with some Western countries. If there is a disruptive technology in Western countries in the future, it may have a huge adverse impact on China's photovoltaic industry.

An embarrassing situation for the United States photovoltaic industry is that demand is far greater than manufacturing. This means that some photovoltaic modules need many imports from China. In terms of market share, the United States is second only to China.

US planned solar power generation will increase from 3 percent of electricity generation in 2021 to 40 percent in 2035 and 45 percent in 2050, achieving nearly half of the nation's electricity supply from solar [26]. In terms of PV installed capacity, the plan is to add an average of 30GW per year by 2025, and eventually reach a goal of 1,600 GW by 2050, which would exceed the electricity consumption of all residential and commercial buildings in the United States combined. This represents the determination of the US government to develop the photovoltaic industry, especially on the manufacturing side. The United States has reasonable photovoltaic technology reserves, if the current favorable policies related to the photovoltaic industry do not change after the presidential election, its photovoltaic industry has great potential for development. It is very likely to compete with China's photovoltaic industry for market share and ultimately achieve the goal of maintaining domestic energy security expected by the U.S. government.

## 4.2. Discussion

The future development of the photovoltaic industry also faces challenges and risks. Environmental issues and the need for technological upgrading may challenge China's reliance on scale and cost advantages [3]. Nonetheless, the US needs to overcome the innovation–production–capacity gap and policy continuity to maintain its comparative advantages [26]. In the future, the focus of China and the US are different. China is prepared to continue to expand its global leadership position by investing in production capacity together with technological innovation to continually improve the efficiency of large-scale manufacturing and handling the environmental issues of large-scale manufacturing technology [27]. The US is planning to dramatically expand its solar capacity by building production capacities, speeding up the technological innovation and professional application of thin-film technology to enhance its market share and energy security [28]. In a globalized market of PV production, high efficiency and low cost that China has achieved by its large-scale production and technologies are well complemented by technological innovation and professional application that the US had made. In this way, both countries' comparative advantages have determined the direction and changed the future of the global PV market with this highly synergistic complementary relationship [10, 26]. In a long term, the global PV industry will also likely continue to evolve and go through a process of competition and cooperation between the two largest PV production countries, China and the US. The win-win relationship between the Chinese large-scale production and cost saving capabilities and the US technological innovation and professional application have or will take both countries to a key position in the global solar market [26]. In the long run of the global PV industry evolution and development, the competition and cooperation between China and the US will likely continue with progress in efficiency, cost reduction and market expansion by both countries [3]. For the governments, China needs to continue to accelerate the technological upgrading and environmental improvement to maintain its leading global position. The US should continue to incentivize innovative capacity and expansion of domestic production to reduce its dependence on imports and enhance its energy security. Both will provide good models for other countries to develop a healthy renewable energy industry and contribute to meet the global goals of climate change [27,28].

## 5. Conclusion

Solar photovoltaics (PV) hold a vital role for the global energy transition towards low-carbon energy sources. PV have the potential to significantly cut carbon emissions and help the world meet vital climate targets. In 2023, PV have 75 per cent of installed capacity in renewable energy thanks to dropping costs and supportive government policies. The next decade will see solar PV continue its leading position among renewable energy sources. The largest PV markets in the world, China and the United States, have become leaders in using PV technology. They bring different models of developing their PV industry to meet future demand for low-carbon energy. China has emerged as the world leader in manufacturing PV. Chinese industry captures more than 80 per cent of the world market. The Chinese state has underpinned large-scale production through five-year plans, subsidies and tax breaks, while maintaining low PV export prices. While China leads in manufacturing crystalline silicon-based PV, the nation lags several western nations in terms of technological innovation. But China also continues to struggle with the growing environmental impact of large-scale manufacturing. The US PV industry focuses on innovation employing a relatively new form of solar technology, thin film. Domestic production still serves as a significant importer to the nation. In 2022, the US Congress passed the Inflation Reduction Act offering large financial incentives to domestic players in the PV industry, hoping to boost domestic production and reduce imports, especially from China. The nation aims to increase Solar's share in electricity supply to 40 percent by 2035. But the US still lags in boosting production to meet demand. In conclusion, the evolving global PV industry will be shaped by two world leaders in this space – China and the US. Chinese focus on scale and low-cost production and the US focus on innovation will create a push to reduce costs and accelerate the global energy transition to low-carbon energy.

## Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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