

Policy Frameworks and Competitive Dynamics in the Photovoltaic Industry: A Comparative Study of China and the United States

Zeyuan Zhao

*School of Arts, University of Bristol, England, United Kingdom
vf22462@bristol.ac.uk*

Abstract: This study provides a comparative analysis of the photovoltaic (PV) industry in China and the United States. By tracing the development of policies, it shows the differences between China and the United States and analyses the differences between industry structure and competitiveness. The findings indicate that China has achieved global market dominance and low-cost production through stable long-term policies, strong financial support, and vertically integrated supply chains, which have allowed it to become the world's largest producer of PV modules. In contrast, the U.S. has been a leader in technological innovation but faces significant challenges, such as fragmented policies, a lack of comprehensive support for the entire PV supply chain, and heavy reliance on imported components. These factors have limited the U.S.'s ability to achieve the same scale of production as China. The study suggests that closer cooperation between the two countries could enhance both countries' competitive advantages, foster innovation, and accelerate the global energy transition to renewable sources.

Keywords: Photovoltaic Industry, Public Policy, Solar Energy.

1. Introduction

This research focuses on a comparative analysis of the photovoltaic (PV) industries in China and the United States, examining the key drivers of each country's PV sector transformation. The central research question is: How do the policy frameworks, industry structures, and competitive dynamics in China and the U.S. shape their respective PV industries and influence global energy transitions? The study seeks to identify the factors that have allowed China to dominate the global PV market and the challenges faced by the U.S. in achieving similar industry leadership. Specifically, it aims to explore the effects of policy continuity, government support mechanisms, technological innovation, and supply chain integration on the competitiveness of the PV industry in both countries. Additionally, the research will investigate the geopolitical and economic factors that impact these countries' positions in the global PV market. By examining these elements, the study will offer insights into how China's long-term, stable policy environment and its comprehensive supply chain integration have fostered its global leadership, while the U.S. has struggled with political instability and fragmented policy support, leading to its reliance on imports and challenges in scaling up domestic production. Ultimately, the research will assess the implications of these findings for future industry trends and the acceleration of global renewable energy transitions.

China and the United States are two of the most influential countries in the global photovoltaic (PV) market. China, as the world's largest producer of solar panels, dominates the global PV manufacturing supply chain, accounting for approximately 80% of global solar panel production as of 2023 [1]. According to the U.S. Department of Energy, nearly 50% of all solar panels sold in the U.S. in 2024 are expected to be imported from China, highlighting the deep interdependency between the two countries in the solar industry. This reliance on Chinese imports has raised concerns about U.S. energy security, especially in light of ongoing trade tensions and the global push toward reducing dependence on foreign supply chains for critical technologies.

The significance of the PV industry is further underscored by the rapid growth of global solar capacity. In 2023, global installed solar PV capacity increased by 87%, reaching 447 GW, driven by large-scale deployments in both developed and developing nations [2]. This growth positions PV technology as one of the most important tools in combating climate change and achieving global decarbonization goals. As part of the broader energy transition, the solar industry's ability to scale efficiently and affordably will play a crucial role in meeting the Paris Agreement targets of limiting global warming to below 1.5°C. Therefore, understanding the dynamics of the Chinese and U.S. PV sectors particularly how they cooperate, compete, and align their policies—will have significant implications for the future of global energy markets and the collective efforts to mitigate climate change. By addressing these issues, this research will contribute valuable insights into the global PV industry and the ongoing transformation of energy systems worldwide

2. Policy Comparison

Their respective policy landscapes have heavily shaped the photovoltaic (PV) industries in China and the United States. In China, the government has implemented a series of structured policies aimed at rapidly expanding PV manufacturing and installation, driven by ambitious goals for carbon neutrality and energy security. China's first major policy step was the Renewable Energy Law in 2005, which laid the groundwork for subsequent policies by officially endorsing renewable energy development [3]. The Golden Sun Program and the feed-in tariff subsidy policy further encouraged investment by providing financial support and setting electricity buy-back rates, which were essential in stimulating rapid industry growth and lowering production costs [4].

As costs dropped, the government began shifting from subsidies to market-driven initiatives. The National Development and Reform Commission's 2013 Regulations on Standards for the PV Manufacturing Industry promoted industry consolidation and set efficiency standards, pushing companies to improve technologies and achieve higher production quality. China's 14th Five-Year Plan underlines the PV industry's role in achieving carbon neutrality by 2060, introducing innovative programs like "PV + energy storage" and "PV + agriculture," which align photovoltaic applications with rural revitalization and smart city development [5].

In contrast, the United States began developing PV policies much earlier but has seen less continuity. Responding to the 1970s energy crisis, the U.S. invested in solar research, creating the Solar Energy Research Programme under the Department of Energy (DOE) [6]. Later, the Investment Tax Credit (ITC), introduced in the Energy Policy Act of 2005, allowed businesses and homeowners to receive tax credits for installing PV systems, a crucial policy supporting PV industry growth [7]. However, the policy landscape has been inconsistent. At the same time, the American Recovery and Reinvestment Act (ARRA) and the Clean Power Plan pushed for renewable energy, the latter was repealed during the Trump administration, reflecting the impact of political shifts [8].

Recently, the Inflation Reduction Act (IRA) extended the ITC, providing renewed federal funding for PV projects and emphasizing the Biden administration's commitment to clean energy transition [9]. However, with the recent shift in political power, there remains uncertainty about the long-term viability of these policies, especially with regard to future federal support.

2.1. Comparison and Discussion

The main difference between China and the U.S. policy framework is that they have continuity and focus of attention. China's PV industry policy has been a stable and long-term approach based on its five-year plan and the overarching national goal of carbon neutrality [10]. Yet, this stability enables Chinese companies to invest long-term, knowing subsidies, financing, and technology-enabled regulation back their investments. For example, such Front Runner Program implemented early on incentivized technological advances by setting high PV module efficiency standards that reinforced China's market leadership by creating reliable and predictable policy surroundings [11].

On the other hand, the US approach is conditioned by shorter-term political priorities, resulting in frequent fluctuations of the policies that are detrimental to investors. For example, the Clean Power Plan underwent repeated changes, resulting in investor and industry stakeholder uncertainty [6]. This inconsistency has prevented the U.S. from reaching the same sustained level of supremacy in the PV industry that it has achieved in its share of the global PV supply chain. Tax incentives, such as the ITC, are the primary tool in U.S. policies. At the same time, in China, the support is comprehensive and multi-layered, goes beyond financial support, and includes policy support. Next, market-driven funding of this type draws the U.S. PV industry closer to external market forces and shifts in political will.

Another major difference is that policy support is available to the entire PV supply chain. From upstream polysilicon production to downstream power generation and installation, China's government has supported Chinese companies integrally, giving these companies a significant cost advantage. The economies of scale that diminish production costs have been enabled with government subsidies, land concessions, and low-interest loans, all of which have helped Chinese companies dominate the world market. Conversely, while U.S. government support is targeted at later stages of the supply chain around technology R&D and installation incentives, there is little in the way of support for upstream production, making U.S. companies reliant on imports and susceptible to supply chain disruptions [12].

These policy differences have affected market competitiveness and investor confidence. Predicated on China's dependable support, it has gained over 80% of the entire world's PV manufacture commercial, while the US has become de jure, apart from a few bidders to take on the globe. Additionally, continuity in China's policy has increased investor confidence and created a stable environment for long-term PV investment. While U.S. firms regularly have to adjust to varying levels of government support, investment is less predictable. It prevents the country from keeping pace with China's production and photovoltaic technology.

3. Evaluation of Industrial Competitiveness

Collecting data from industry reports produced by the International Energy Agency (IEA), market analysis by the International Renewable Energy Agency (IRENA), and international trade data from the World Trade Organization (WTO), this study evaluates the industrial competitiveness of China and the United States photovoltaic (PV) sector [13]. Metrics such as supply chain integration, production costs, and global market share are measured. Then, China's share of global PV module production and raw material processing is compared to that of the U.S., and cost advantages are discussed along the supply chain, from the sourcing of raw materials to the downstream installation.

The baseline for comparison of the production efficiencies consists of quantitative methods including market share analysis and cost benefit comparisons. In addition, government subsidies, tax incentives and regulatory frameworks of policy impact assessment were also studied. The phenomena are also associated with broader competitiveness factors, such as policy consistency and government-backed finance, through the analysis of qualitative indicators [14].

3.1. Industry Status Overview

The global PV industry is highly competitive. China currently dominates production, holding over 80% of the global PV supply chain, including upstream components such as polysilicon and downstream solar module manufacturing [15]. This dominance results from supportive government policies, technological improvements, and economies of scale. Meanwhile, inconsistent policy support has hindered U.S. PV industry development, which impacts domestic manufacturing capabilities and leads to a reliance on imports for key components [16].

Despite significant U.S. investments in PV technology, its market share in global PV manufacturing is below 10% [13]. The U.S. focuses primarily on tax-based incentives and research and development (R&D) subsidies rather than integrated supply chain support. Consequently, American firms face challenges in achieving competitive costs, particularly against the backdrop of China's scale advantages and streamlined production processes.

3.2. Drivers of Competitive Differences

Several key factors, such as policy stability, financial backing, technological advancement, and supply chain integration, are in the Chinese PV industry, which struggles to maintain its competitiveness gap with the US PV industry.

Policy Stability: China's PV policy landscape has been consistent in the long term, including, for instance, the Five-Year Plans, which are very clear and give clear directives for renewable energy targets [17]. By enabling continuous investment and expansion of PV technology in a predictable environment, this stability also increases competitive advantage for U.S. businesses in clean technology markets. However, U.S. PV policy is more susceptible to political shifts than U.S. policy, with much greater policy reversal seen, for example, in repealing the Clean Power Plan under the Trump administration [18]. Such erratic policy fluctuations cause a lack of investor confidence and create uncertainty in the PV sector, discouraging strategic industry planning.

Financial Support and Incentives: China's financial support extends across the entire PV value chain, encompassing subsidies, low-interest loans, and land concessions [10]. These incentives reduce production costs, allowing Chinese firms to operate with significant economies of scale. Local governments in China also provide financial incentives to support PV installations, making it easier for companies to expand their operations domestically [19]. In contrast, U.S. financial incentives are primarily tax-based, such as the Investment Tax Credit (ITC), which relies heavily on private sector investment [20]. This reliance on tax credits rather than direct subsidies limits the cost-competitiveness of U.S. PV companies. It reduces the potential for economies of scale that China's integrated financial support model achieves.

Technological Advancements: Technological innovation in PV efficiency has been a central focus for both countries; however, China's approach has yielded more immediate, cost-effective advancements. Through programs like the Front Runner Program, China has incentivized high-efficiency module development, resulting in PV technologies with higher conversion rates and lower manufacturing costs. The U.S., while a leader in high-efficiency technology development, struggles with commercialization and scaling due to less comprehensive support for downstream manufacturing, limiting its competitive advantage in mass production.

Supply Chain Integration and Raw Material Access: China boasts a long-standing assembly line for solar from upstream to polysilicon production through to component manufacture and installation. This vertical supply chain integration produces a cost effect for Chinese production and, therefore, a pricing advantage in the global market. Moreover, the very heart of PV manufacturing, polysilicon, is the raw material that China has heavily invested in and has control of. However, due to the fragmentation of the supply chain and heavy reliance on foreign components, the U.S. is vulnerable

to trade restrictions and experiencing increasing production costs [9]. U.S. companies also find it difficult to achieve the same or close to the same economies of scale as Chinese companies due to the lack of a fully integrated supply chain.

China's long-term policy planning, comprehensive financial support, pointed tech incentives, and full supply chain integration have given China a competitive edge in the PV industry. On the other hand, discontinuity and limited upstream integration within the U.S. policy framework have prevented the U.S. from effectively competing. These are some of the reasons why China can grab a larger share of the global PV market and be the leader in renewable energy transition worldwide.

4. Industry Outlook

As demonstrated in Table 1, China and the United States photovoltaic (PV) industrials have different trajectories driven by technology, export pattern, political situation, and interlinks of supply chain.

Table 1: Comparative Analysis.

Dimension	China	United States
Technological Status	Focused on high-efficiency modules and innovative applications (e.g., PV+ Agriculture, PV+ Storage).	Advanced R&D in PV technology, but limited in commercialization and scaling.
Export Market Development	Dominates global markets with over 80% of module manufacturing capacity.	Minimal export market presence; primarily serves domestic demand.
Political Outlook	Stable, long-term policies aligned with Five-Year Plans and carbon neutrality goals.	Political uncertainty affects policy consistency; state-level efforts counterbalance federal challenges.
Supply Chain Integration	Fully integrated from polysilicon production to module installation.	Fragmented; heavily reliant on imported components and foreign supply chains.

4.1. China's Prospects

China's PV industry enjoys comprehensive policy support, and seamless collaboration with the domestic supply chain that enjoys overwhelming global market presence. The technological developments in this area aim at advancing PV module efficiency and PV integrating new applications (PV+ models). Traditional energy systems are being replaced by multi-functional energy hubs, that also increase land use efficiency and rural economic development – programs like PV + Agriculture and PV + Energy Storage [21]. All these also part of China's larger aim to be carbon neutral by 2060.

As with all of China's clean energy manufacturing, export markets are a key pillar of China's strategy, with more than 80% of global PV module manufacturing capacity shared across China [14]. Cost advantages from economies of scale and supply chain integration power this dominance.

Remaining export growth is weighed by geopolitical factors, such as tariffs and trade restrictions from where its biggest export markets, the U.S. and Europe.

Economically, China's centralized economy plans make it a reliable market for PV industry. Energy security and rural revitalization will play an important role in the PV sector under the framework of the 14th Five-Year plan, bringing steady government support.

China has a completely integrated supply chain starting from polysilicon upstream production and moving downstream to module assembly and installation. This vertical integration cuts costs and improves resilience from supply chain disruptions to put the country at the forefront of renewable energy development at the global level.

4.2. U.S. Prospects

Political uncertainties and lack of coherence in policy frameworks create problems for the U.S. PV industry. Even with advanced PV technologies, the limited supply chain integration has led to hurdles for commercialization and introduction at the large scale. Owing to technological innovation in the field of high efficiency modules and smart inverters, the U.S. leads the world in PV R&D. Nevertheless, its lack of domestic manufacturing infrastructure cripples it. The industry lacks indigenous supplier base, hence imports of critical components, especially from China due to which the industry becomes vulnerable to trade disruption. Lack of cost competitiveness and very limited domestic production capacity are constraining export market development. Compared to China's, U.S. exports are almost nonexistent, and most domestic production is for consumption in the country. Changes in the US PV industry are greatly influenced by political changes. Despite the promise attached to the recent Inflation Reduction Act, federal incentives for renewable energy could be overturned by future political changes. States like California and New York jump ahead with aggressive renewable energy targets, but federal and state miscue impedes coordinated development. Overall, the U.S. supply chain is fragmented and lacks upstream polysilicon production capabilities and is highly dependent on imports from the rest of the world. Specifically, reliance enhances production costs and constrains the industry's competitiveness at scaling compared to global players such as China.

5. Conclusion

In conclusion, the comparative analysis of the photovoltaic (PV) industries in China and the United States reveals significant differences in their policy frameworks, industry structures, and global competitiveness. China's success in dominating the global PV market can be attributed to its long-term, stable policy environment, comprehensive government support, and integrated supply chain. The Chinese government's consistent backing through subsidies, low-interest loans, and targeted programs like the "PV + Agriculture" and "PV + Energy Storage" initiatives has enabled companies to achieve economies of scale, drive technological advancements, and maintain a competitive cost structure. Furthermore, China's vertically integrated supply chain—from polysilicon production to module manufacturing and installation—has provided it with a significant cost advantage, reinforcing its position as the world's leading supplier of PV modules. Both countries' PV industries are crucial to the global renewable energy transition, yet their contrasting policy approaches, and industrial structures underscore the importance of stability, collaboration, and long-term vision in fostering sustainable energy solutions. Given the current trends, the future of the global PV market will depend heavily on whether the U.S. can create a more cohesive and predictable policy framework that incentivizes domestic manufacturing and reduces its dependence on foreign imports, and whether China can maintain its leadership amid rising geopolitical tensions and trade restrictions. Strengthened cooperation between the two countries could potentially lead to an accelerated global

energy transition, ensuring that solar energy plays a pivotal role in mitigating climate change and driving global decarbonization efforts.

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