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Regulatory Impacts on the Development of Solar Industry in China: A Policy Analysis

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Abstract: Traditionally, China's energy structure has been dominated by coal, but China is trying to make transition towards renewable energy sources such as solar, wind, and hydroelectric power. Among these energy, solar energy plays a crucial role due to its scalability and reduction of cost. This study explains the impact of government policies on the development of solar industry and how China become a global leader in this sector, and strategies employed to fix the problem of overcapacity. By employing a mixed-method approach, including current status of the solar industry, case studies, and policy analysis, this paper examines the impact of policy frameworks, both historical and contemporary policies. It aims to provide insights for policymakers and industry stakeholders through evidence-based recommendations designed to optimize policy frameworks, support industrial growth, and promote sustainable development. Lastly, this research seeks to give a broader understanding of how government policies can nurture a resilient and competitive solar industry, thereby promote the development of renewable energy technologies and environmental management.

Keywords: Solar industry, solar power, renewable energy.

1. Introduction

Over the past decades, the global solar industry has experienced rapid growth because of technological developments and cost reductions. China has been the leader of this growth, not only as a major consumer but also as the leading producer of solar photovoltaic (PV) panels. Driven by domestic demand and export markets, China's solar industry has been growing quickly. China now holds some of the world's largest solar PV manufacturers and being the biggest country in terms of installed capacity. Without government support, it would have been impossible for China's solar industry to match and even surpass its competitors in both technology and production capacity within two decades. One of the biggest factors driving the development of China's solar industry is government policy guidance. Regulatory frameworks that aim to promote innovation and development have profoundly shaped the growth of this industry, in both sustainability and competitiveness. However, this approach has also encountered some problems, such as the curtailment of solar power due to overcapacity. Given the significance of the solar industry in China, understanding how government policies influence its development is crucial. This research aims to

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answer how did government policies influenced the development of China's solar industry, and what are the implications for the future development of solar industry.

This paper seeks to analyze the impacts of government policies on the solar industry in multi-aspect and propose suggestions for policy improvements. To achieve these objectives, a mixed-method approach combining solar industry reviews, policy analysis, and case study will be used. This research endeavors to contribute to the sustainable development of the solar industry and policy decisions guiding its future growth. Through an evidence-based approach, the findings give some insights for policymakers and stakeholders, in order to build a resilient and competitive solar industry in China.

2. Current Status of China's Solar Industry

2.1. Solar Industry

In order to meet the challenge of global warming and reduce dependence on fossil fuels, a global shift to renewable energy sources is accelerating. Countries around the world are increasingly investing in renewable energy such as solar, wind, and hydro. As shown in Figure 1, there has been a significant increase in installed solar and wind capacity since 2016, with prediction showing a trend that continue upward. Governments, especially the Chinese government, are implementing support policies, including subsidies and preferential electricity prices, to encourage the spread and innovation of these renewable energy. Despite these positive developments, challenges remain, such as ensuring grid stability and integrating renewables into existing energy infrastructures. Nonetheless, the commitment to expanding renewable energy usage signifies a pivotal step towards achieving global sustainability goals and fostering an environmentally friendly future.

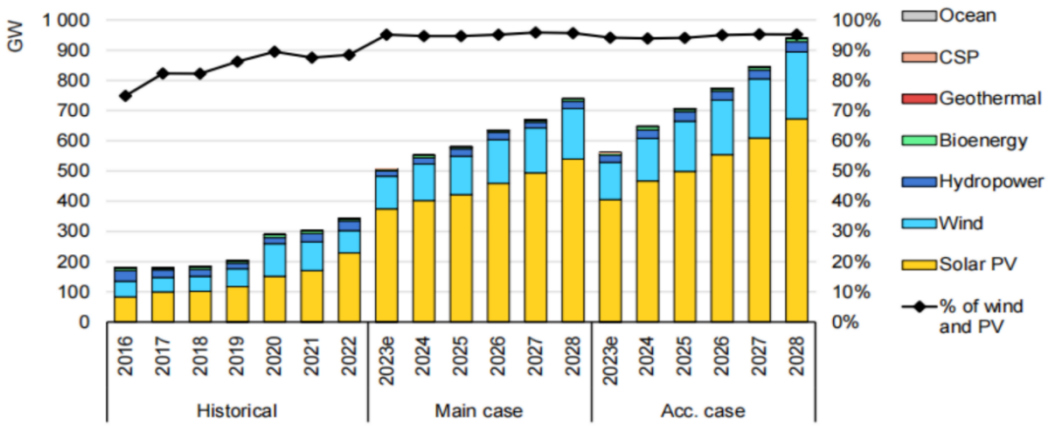

Figure 1: Renewable electricity capacity additions by technology and segment [1].

Notably, the current global renewable energy growth is predominantly driven by China. As shown in Figure 2, since 2005, renewable energy capacity has been on a continuous rise, with China registering the highest growth among these nations and regions, exceeding the combined growth of the United States and the European Union. These data demonstrates that China's efforts in advancing renewable energy have far outpaced those of other major economies, positioning it at the forefront of the global shift towards cleaner, more sustainable energy solutions.

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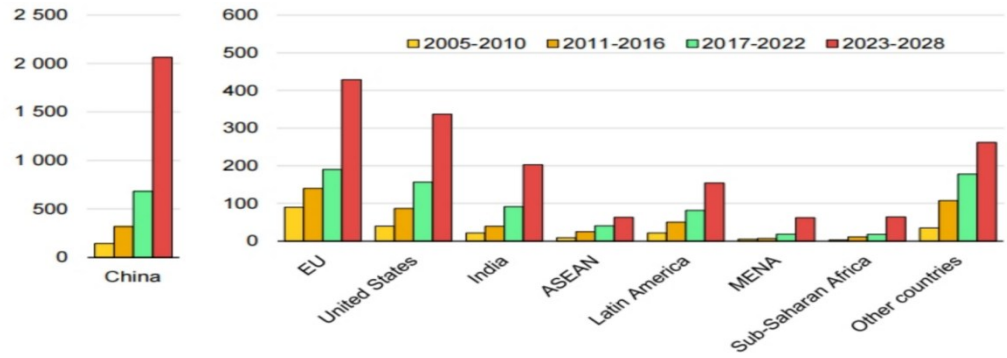

Figure 2: Renewable electricity capacity growth by country/region, main case [1].

A significant portion of China's renewable energy growth comes from solar energy, which is one of the most important parts within its renewable energy sector. As shown in Figure 3, solar energy plays a leading role in the growth of renewable energy sources in the world. Given the fact that China has substantial share in this domain and many reports from the Chinese government, it is evident that China dominates the current solar industry landscape. According to China National Energy Administration, as of 2024, China's total installed power generation capacity reached 3.071 billion kilowatts (kW), with solar power installations accounting for 714 million kW, making it the second-largest power source after coal, representing 23.24% of the total capacity. In terms of market share, China produces 85% of the world's solar cells, 88% of solar-grade polysilicon, and 97% of silicon rods and wafers required for solar energy production. The current data suggests that China holds approximately 15% of the global solar market. According to the International Energy Agency (IEA), in 2022, China accounted for more than 80% of global photovoltaic (PV) production. By mid-2022, China's cumulative installed solar capacity reached 336.2 gigawatts (GW), constituting about one-third of the global total capacity [1].

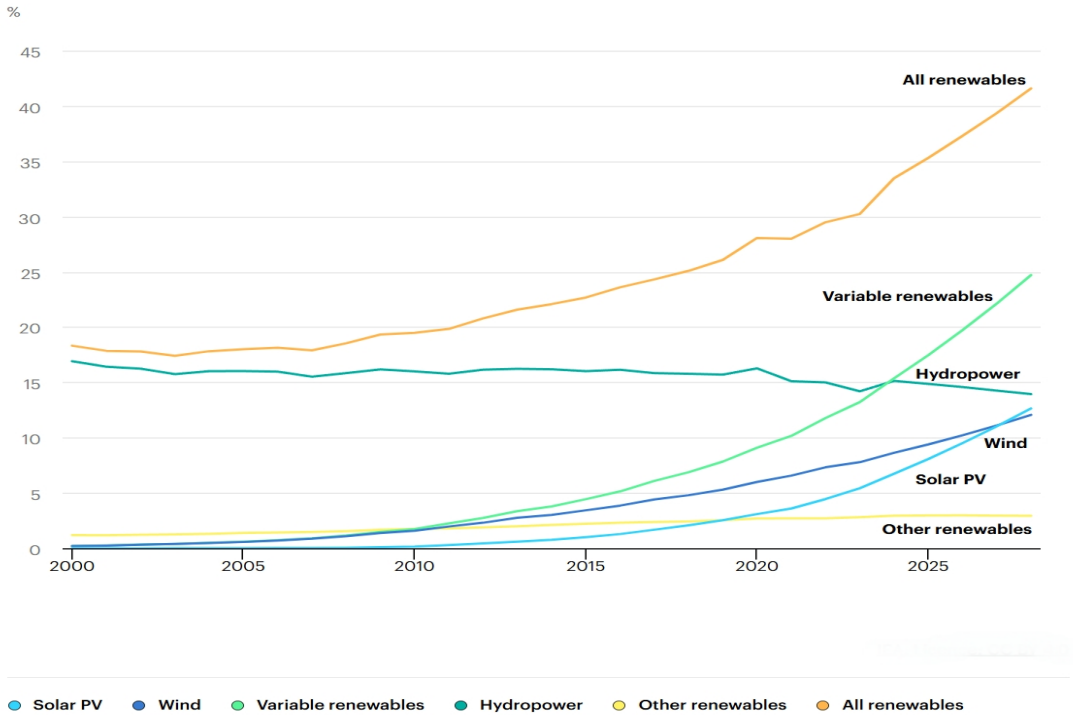

Figure 3: Share of renewable electricity generation by technology (2000-2028) [1].

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For China's solar industry development, policy support has been crucial, including measures such as tax reductions, financial subsidies etc. In 2022, the National Development and Reform Commission issued the "Smart Photovoltaic Industry Innovation and Development Action Plan (2021-2025)", aiming at advancing the integration of new-generation information technology with the photovoltaic industry to enhance the entire solar industrial chain to a more intelligent level. Additionally, the State Council released the "14th Five-Year Plan for Modern Energy System" in 2021, outlining strategies for developing renewable energy and promoting sustainable growth. Examples of policies include solar subsidy schemes and feed-in tariffs, financial support policies, and tax incentives. There are many other relevant policies including reduction of carbon emissions and promotion of clean energy as environment protection measures. The implementation of these policies has directly affected the development of the China's solar energy industry. However, challenges and problems remain, such as how to ensure policy implementation effective, adverse changes in the solar market, and technological barriers in achieving sustainable development. Despite the challenges, the common goal of these policies is to achieve sustainable development, and also to consolidate China's leadership in solar energy.

2.2. Issues and Trends

The intermittency and non-schedulability of solar power production rises problems to the stability of the power grid, especially in regions with high solar penetration. To solve these problems, wind power and hydro power can be used as complementary energy sources during periods of insufficient solar power generation. Energy storage systems (ESS) can solve this problem by reducing the burden of power grid management and mitigating the intermittency issues associated with solar power generation [2]. ESS technology can integrate renewable energy into the grid better, making operations of the power grid smoother and more reliable.

The problems with solar are not limited to intermittency. Due to overcapacity, China is currently trying to solve the "Curtailment" problem. "Curtailment" refers to the situation where solar power generation capacity is sufficient, due to factors such as grid access restrictions, insufficient power demand or improper power system scheduling, solar power plants are not fully utilized, resulting in forced solar curtailment. In China, with the rapid development of the solar industry, especially in the western and northern regions rich in solar resources, a large number of solar power stations have been built and connected to the power grid [2]. However, local power consumption capacity is limited, and there are bottlenecks in power transmission in the major power-consuming provinces in the east and south, leading to severe power curtailing in some areas.

In response to these problems, the Chinese government has taken a series of measures, including strengthening cross-regional power transmission capacity building, optimizing power market mechanisms to improve the utilization rate of renewable energy, and promoting the development of energy storage technology. These efforts aim to balance electricity supply as well as demand and reduce curtailment rates, thereby making more efficient use of solar energy and promoting the transition to a cleaner energy transition [3]. In addition, through the development of technology and the reduction of costs, distributed photovoltaic power generation has been further promoted, which helps to alleviate the pressure of centralized power plants to abandon electricity. While these measures have reduced energy waste, problems remain.

China's policy support for the solar industry dates back to the "New Energy and Renewable Energy Industry Development Planning 2000-2015," when silicon materials and production technologies required for solar cell manufacturing were largely dependent on imports. China began providing special support to the solar industry through incentive policies and research projects. Since then, China's solar technology rapidly developed, surpassing the EU to become the largest producer of solar cells within a decade, achieving over 50% self-sufficiency in silicon needed for battery production.

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Furthermore, China increased electricity price subsidies for solar power in order to promote solar energy. In 2006, the government introduced the "Interim Measures for the Management of Renewable Energy Power Price and Cost Sharing", aiming at providing long-term electricity price subsidies for renewable energy projects. The 2009 "Renewable Energy Law" further increased subsidies for solar electricity prices, accelerating the adoption of solar energy and the development of the solar industry.

However, after 2010, the United States and the European Union increased tariffs on Chinese solar products which significantly reduced the market, coupled with a gradual reduction in domestic solar electricity price subsidies starting from 2011, the marketing environment for China's solar industry kept getting worse. Many Chinese solar companies went bankrupt during this period [2]. During this time, China's policy shifted from direct fiscal subsidies to reducing intervention, allowing the solar industry to gradually move towards marketization. This transition is designed to encourage innovation and improvements on efficiency within the solar industry.

3. Regulatory Policy Analysis

3.1. Positive Policy Effect

Government policies, including financial subsidies, tax incentives such as the "Smart Solar Photovoltaic Industry Innovation and Development Action Plan (2021-2025)" have significantly pushed technology innovation and market expansion of China's solar industry. These policies have encouraged companies to invest more in research and development (R&D), leading to advancements such as more efficient solar cells and integrated smart solar photovoltaic systems. For instance, these policies have facilitated breakthroughs in heterojunction (HJT) and TOPCon battery technologies, enhancing conversion efficiencies and reducing costs [4]. The policy support has also enabled the integration of artificial intelligence and big data analysis into solar power systems, improving efficiency in operation and maintenance. Moreover, the government's attention on environmental protection and sustainable development has further propelled the solar industry towards environmental protection [5]. By promoting the recycling of solar panels and other waste materials, China is working towards a circular economy within the solar power. This effort not only reduces negative effect on environment but also creates more business opportunities for recycling enterprises and fosters job creation in related industries.

Chinese solar products dominate the global solar market, with a market share exceeding 80% by 2022. Leading enterprises like LONGi, JinkoSolar, Trina Solar, and Tongwei are recognized worldwide for their high-quality products and advanced technologies. Government support has helped these companies to scale up its production and reduce costs, thereby enhancing their competitiveness of their products internationally. By mid-2022, China's cumulative installed solar capacity reached 336.2 GW, constituting about one-third of the global total [2]. The international competitiveness of Chinese solar products is further bolstered by continuous improvements in manufacturing processes and standards of quality control. Under the guidance of government's policies, numerous solar energy companies rapidly grew into global leaders. Notably, many of today's leading enterprises were established after 2000. For instance, LONGi, listed among China's top 500 companies, was founded in 2000. While another top 500 company, JinkoSolar, was established in 2006. When these future leaders were established, China's solar production was still heavily reliable on imports from foreign countries. Without government support, it would have been impossible for them to swiftly grow and become competitive, surpassing other foreign solar companies within just over a decade and beginning to export their products abroad. The rapid rise of these companies can largely be attributed to strategic government policies that fostered innovation, reduced dependency on foreign technology, and promoted domestic manufacturing capabilities. This enabled Chinese solar companies to meet local solar power demand and also to penetrate international markets.

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Support from the government included financial incentives, subsidies for R&D, as well as favorable regulations aiming at nurturing a robust solar industry ecosystem. As a result, these companies managed to achieve significant technological advancements and cost reductions, positioning themselves at the leader of the global solar industry. Their success also marks a pivotal shift in China's role within the renewable energy sector, transforming from a importer to a major exporter of solar technologies. For example, LONGi Green Energy Technology has established itself as a global leader in monocrystalline silicon technology, setting new benchmarks for efficiency and reliability. Additionally, Chinese companies are increasingly participating in international projects, contributing to the global energy transition while showcasing their capabilities abroad [6].

Promoting the development of renewable energy has been a major goal for the Chinese government for a long time, because China has been trying to achieve carbon neutrality as well. This effort reflects on its support for the solar energy industry. China's commitment to fostering renewable energy sources echoes its broader environmental objectives, including reducing carbon emissions and combating climate change. By supporting the growth and innovation within the solar industry, the government is taking significant steps towards its carbon neutrality goals. The synergy between these efforts shows China's dedication to transitioning towards a cleaner, more sustainable energy future, leveraging its leadership in the solar industry to make both domestic and global progress in renewable energy adoption. By the end of 2024, it is expected that solar power will play a critical role in reducing greenhouse gas emissions and improving air quality, thereby supporting China’s commitment to carbon neutrality [4]. According to estimates, every additional gigawatt of solar capacity can potentially avoid millions of tons of CO_2 emissions annually [7]. Furthermore, the deployment of distributed solar systems, such as rooftop installations and building-integrated photovoltaics (BIPV), is helping to decentralize energy generation and promote local consumption. This approach not only enhances energy security but also supports rural electrification, providing clean energy solutions to remote areas without relying on traditional grid infrastructure.

3.2. Negative Policy Effect

While subsidies have helped stimulate growth of the solar industry, they can also lead to unfair competition. Companies receiving government substantial support may have an undue advantage over those companies who do not, potentially stifling innovation and competitiveness among startup companies [8]. This distortion can hinder the natural evolution of the solar power market and create barriers for entrants. For example, some small and medium-sized enterprises (SMEs) might find it impossible to compete against larger corporations that benefit from extensive state funding, because they do not have enough capital to start up business to begin with [2]. Additionally, excessive reliance on subsidies can lead to inefficiencies and wasteful investments. What’s more, companies may prioritize short-term gains over long-term sustainability, resulting in suboptimal resource allocation. To mitigate these risks, policymakers should consider phasing out direct subsidies gradually and introducing performance-based incentives instead.

The solar industry's heavy reliance on government subsidies brings risks. Any changes or reductions in capital could severely influence business operations and sustainability, which again shows the need for diversification and reduced dependency on national support. Enterprises must try to develop self-sustaining business models that are less vulnerable to policy fluctuations. For instance, many companies are exploring new revenue streams through value-added services such as system design, installation, and maintenance, which offer higher margins compared to hardware sales alone [2]. Moreover, fostering a innovation culture and entrepreneurship within the industry can help build resilience against external shocks. Encouraging collaboration between academia and industry can accelerate R&D efforts and facilitate the commercialization of cutting-edge technologies [9]. Besides, frequent policy adjustments create uncertainty for businesses. Changes in subsidy levels, feed-in

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tariffs, or other regulatory frameworks can affect long-term planning and investment decisions, impacting profitability and growth prospects. Therefore, enterprises need to maintain flexibility and resilience to adapt to evolving policy landscapes. One strategy is to adopt flexible management practices that enable quick responses to changing market conditions and regulatory requirements. For example, during periods of policy uncertainty, companies can focus on diversifying their product portfolios and expanding into new markets. By leveraging expertise in their core technologies, companies can develop innovative applications that cater to emerging trends, such as floating solar farms or hybrid systems combining solar with wind or storage solutions.

The effectiveness of policy implementation varies across different regions due to different economic conditions, infrastructure availability, and administrative capacity. For example, Xinjiang leads in utilizing solar energy because of abundant sunshine and vast desert areas, whereas other regions might face difficulties in deploying similar technologies efficiently [10]. Understanding these regional disparities is crucial for formulating targeted strategies to optimize policy effectiveness. In less favorable regions, governments can provide additional support through infrastructure upgrades or specialized training programs to improve local capabilities. Furthermore, regional differences in climate and geography necessitate customize approaches to solar deployment. For instance, coastal provinces may benefit from offshore solar installations, while mountainous areas require customized designs to maximize sunlight exposure [3]. Policymakers should engage with local stakeholders to ensure that policies are adapted to meet specific regional needs. Occasionally, there is a lack of coordination between policies, which can result in inefficiencies or conflicting objectives. For instance, while one policy aims at boosting domestic consumption, another might focus on export promotion, creating potential conflicts for manufacturers trying to navigate both markets simultaneously. Improving policy coherence is essential to ensure consistent and effective implementation. To solve these potential problems, government can establish inter-departmental committees or task forces dedicated to coordinating policy efforts. In addition, improved communication channels between central government and local governments are necessary to ensure that national-level policies are effectively translated into actionable plans at the grassroots level. Feedback mechanisms involving industry representatives and experts can provide valuable insights into policy effectiveness and inform future revisions.

3.3. Case Study: LONGi

Taking large-scale solar enterprise like LONGi Green Energy Technology as an example, one can see how government policies have influenced its development. LONGi has benefited from supportive policies that fostered rapid growth and technological advancement. However, the company must deal with the risks associated with policy dependencies and adapt to changing regulatory environments.

LONGi Green Energy Technology exemplifies the profound impact of government policy on growth of company within China's burgeoning solar industry. Established in 2000, LONGi emerged during the period when China was laying the foundation for its renewable energy industry through initiatives such as the "New Energy and Renewable Energy Industry Development Planning (2000-2015)". This early governmental support was pivotal, providing LONGi with the necessary capital to grow in an environment where solar cell technology and materials were predominantly imported. Moreover, Chinese government's commitment to renewable energy has been consistent, with legislation like the "Renewable Energy Law" introduced in 2009, further laying the foundation for companies like LONGi [11]. These policies provided financial subsidies and established favorable market conditions that encouraged innovation and expansion as well. As a result, LONGi was able to expand its operations from semiconductor material manufacturing to becoming a leader in monocrystalline silicon wafers and subsequently, a vertically integrated photovoltaic product manufacturer. Since 2021, LONGi has been the world's largest photovoltaic company by market value.

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Moreover, the government's strategic on reducing carbon emissions and achieving carbon neutrality has directly influenced LONGi's development trajectory. Initiatives aimed at optimizing the power market mechanism and promoting the development of energy storage technologies have supported LONGi's efforts to solve challenges such as curtailment. At the same time, promotion towards distributed power generation has opened new markets for LONGi, allowing it to diversify its products and reduce reliance on centralized power stations.

Through this case study, it is evident that while government support plays a crucial role in driving the solar industry forward, companies must strive for self-sufficiency and innovation to reach long-term success within evolving policy landscapes. LONGi's development shows the importance of balancing government assistance with internal R&D initiatives. Despite benefiting from subsidies and favorable policies, LONGi has consistently invested in developing proprietary technologies, such as its advanced monocrystalline silicon wafers, which have set industry standards for efficiency and cost-effectiveness. This dual approach has enabled LONGi to maintain its competitiveness even as the policy landscapes shift.

4. Conclusion

This study discusses multifaceted influence of government policies on China's burgeoning solar industry, highlighting both positive outcomes and new challenges. It is evident that supportive government policies have played a pivotal role in fostering innovation and market expansion within solar industry. Financial incentives, tax benefits, and strategic plans aimed at enhancing technological development have propelled Chinese solar companies such as LONGi to the leader of global solar industry. These measures not only promoted improvements in solar energy technology but also contributed to substantial environmental benefits by reducing carbon emissions and expanding sustainable energy application.

However, there are substantial challenges like the tariffs imposed by the United States and the European Union, the saturation of the domestic market, and the curtailment problem. Tariffs have reduced the competitiveness of Chinese solar products in international markets, leading to a decline in export opportunities for companies like LONGi. Meanwhile, the rapid expansion of solar power capacity has outpaced local consumption capabilities within China, resulting in severe curtailment problems where generated solar power cannot be fully utilized due to power grid limitations and imbalance between production and demand. To solve this problem, it is crucial to gradually phase out direct subsidies while introducing performance-based incentives. Such a shift would encourage companies to focus on innovation and efficiency rather than seeking short-term gains through state funding. Diversification of business models and exploration of new revenue source beyond hardware sales can enhance resilience against external shocks. Enhancement of regional coordination and fair competition are equally important. Establishing inter-departmental committees to coordinate different policies can mitigate inefficiencies and conflicting objectives problem. Furthermore, promoting transparency and equal access to financing opportunities will foster a healthier competitive environment.

Lastly, continued effort on environment protection remains essential. By encouraging recycling and environmental measures, the government can reduce negative impact on environment and opens up new business opportunities as well as job creation in related industries. Adopting these recommendations, policymakers can ensure the long-term success and sustainability of China’s solar industry, contributing to both economic prosperity and environmental governance. This balanced approach will be crucial in navigating potential challenges and seizing opportunities in the rapidly evolving solar industry.

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