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Powering the Future under Geopolitical Pressure-PV Industry Analysis for China and USA

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Abstract. This paper examines the current state of the photovoltaic (PV) industry, which is a significant contributor to global environmental protection efforts. The PV industry's status is closely linked to environmental sustainability, one of the most pressing issues of our time. This study evaluates the current situation of PV panels, assesses potential risks to the industry's stability, and proposes solutions to mitigate these threats. The analysis focuses on China and the USA due to their significant roles in the global PV market and their anticipated future influence. By examining the economic perspectives and geopolitical factors affecting the PV industry in these two countries, this paper aims to provide a comprehensive understanding of the current dynamics and future outlook. Government policies, including supply-side measures like tax incentives and demand-side initiatives such as feed-in tariffs, heavily influence China's PV industry. Recent trends indicate a shift towards marketization and refinement. In contrast, the US PV industry is driven more by market-based demand-side policies and is significantly impacted by economic factors and geopolitical considerations, including trade protectionism aimed at safeguarding its new energy sector. Through this comparative analysis, the paper seeks to identify the strengths and weaknesses of each country's approach, offering insights into how the global PV industry can navigate its challenges and continue to contribute to environmental sustainability.

Keywords: Geopolitical Pressure-PV Industry; China; USA.

1. Introduction

The photovoltaic cell, or PV cell in short, is one of the major products used to convert solar energy into electricity. It makes up more than 60% of solar-based electricity generation and, thus, 12% of total renewable energy generation in 2021 [1]. The PV cell stood out amongst all means of electricity generation as it is the only kind that directly converts the input energy into electricity, without all the mechanical intermediate steps, which in turn results in an unrivaled conversion ratio and efficiency, at least theoretically. Also, as the result of the debasing from the mechanical intermediator, the individual component required to function is extremely small in comparison to others, thus enabling it to be used in previously unreachable positions for electricity generation.

Beneath the bright future this technology could behold, the current industrial status looks much grimmer. The high price nature of the PV cell makes it extremely inefficient in large-scale electricity generation, thus outright ruling it out from the major market. Along with it is the lack of efficiency in energy conversion, as the current technology only enables the PV panels to have around 12% conversion rates, lower than the 15% presented by wind turbines and much lower than the theoretical limit of 80% for PV panels [2]. The derailing of the PV panel industry from its theoretically optimized form resulted in declining governmental support in this field.

However, in recent years (after 2020), the PV panel has witnessed a resurgence as a breakthrough in polysilicon production, one of the major components of PV panels, caused PV panel production to skyrocket by 200% in the last 5 years (IEA) and governmental support rises again in this new field in renewable energy [3].

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2. Background Information on the Industry

The idea of converting solar power to electricity has been an idea for a long time. In the 1950s, the concept of directly converting sunlight into electricity was proposed and thus widely experimented around the world. Despite the first PV panel being created as early as 1956, the high cost and low efficiency, along with its fragileness and inconsistency, resulted in the confinement of this idea in the lab, unable to be commercialized until the 1990s [4].

The commercialization of this technology only began in the 1990s, when technological improvement in this field resulted in a breakthrough in the quality of PV panels, thus making commercialization possible. The reorientation of the environmental crisis and widespread promotion of renewable energy caused the initial expansion of the PV cell industry.

The industry then stagnated over the next decade until governmental policy and subsidy provided a new wave of interest in this field, making the industry no longer rely on technological advancement in professional labs that have no relations with the industry but a self-sustaining group of enterprises that could fund its own technological improvement.

3. PV Cell Industry Market Status and Competitiveness

3.1. China's Current Market Position and Competitiveness

China, with its leading company- Trina solar, presents a great cost advantage of 15% (IEA) in comparison to the US-made counterpart. This cost advantage, along with the improvement in the production of monocrystalline silicon, drastically increased the scale of production in PV cell production, with a 260% increase through 2017-2022, and currently dominating the global market with an 85% occupation rate (IEA) [5, 6]. This domination of the market threatens a global monopoly, where IEA expresses direct concern about the possible deficiency that may result from such domination. The cost advantage is still mimicked in ASEAN and India-produced PV cells, yet the scale of production is limited in these regions due to a lack of efficient supply chains and the lack of skilled workers that are required for certain procedures during the production, thus resulting in a bottleneck in the capacity of production (IEA).

The current quality of production in China matches the standard level that was acknowledged internationally, with no major flaw that stands out from other products in other countries. PV cells in China lack some frontier improvement that has made a subtle increase in the conversion rate of energy, yet such improvement does not provide any major advantage for any player. Apart from the production of PV cells itself, China also dominates the upstream raw material production and downstream packaging and installation.

The domination, however, also comes along with setbacks from politics and foreign relations. With an ever-mounting tariff and outright banning of Chinese products from being imported, this proves a major challenge for Chinese producers as such limitation greatly reduces the ability to export products to some of the largest markets, including the US and EU. This also comes with the unwillingness and inability of frontier research, with a major lack of advanced laboratories for such research and the tilted focus on production improvement rather than frontier research.

3.2. US Current Market Position and Competitiveness

The US, though only occupying a far smaller portion of the market than a decade ago (IEA), has only 0.8% of PV cells made in the US. Such reduction comes not only from the lack of a frontier breakthrough in conversion rates but also from the high cost of production in the US. The problem of high production cost is suffered in numerous Western countries, but due to the rapid deindustrialization process and exporting of industrial capabilities to countries of lower production cost in the 1990s, the US suffered the most severe impact with its domestic industrial capabilities [7]. As of 2022, the US has nearly 2 times higher personnel cost (IEA) in comparison to China or India.

Going along with the already crippling disadvantage with production cost, the indiscriminate tariff raised under the Trump administration barred US products from not only entering the Chinese market, the biggest installation market by far (IEA), but also from India, ASEAN countries, and European countries, mainly due to the retaliatory tariff in response to the US tariff rise. This put the US-made product at a further disadvantage, as the extra tariff added to the cost disadvantage that US PV cells already had.

US-made products also had multiple other disadvantages, mostly in relation to the rapid deindustrialization. A lack of adequate supply lines and high personnel costs cause new start-up companies to be unable to build up enough competitiveness before being outcompeted by cheaper and better foreign products in the market. The result is that US-made PV cells barely have any competitiveness in the market and can only be cradled under the protective tariff.

The protective tariff under the Trump administration had one other use than making the US make PV cells harder to export, and that is its near absolute protection of the domestic US market. The tariff imposed on imported PV products was sufficient to eradicate the previous competitive difference in the market and allow complete dominance over the domestic market, which consists of 17.6% of the worldwide demand (IEA), providing a solid base for the growth of the industry [8].

Despite the grim market occupation, the current resurgence of US industrial capacity would also affect the PV industry and thus result in an expected increase in the total market occupation from 0.8% to 3.5% in 2027(IEA) [9, 10]. Thus, the US PV cell industry is expected to witness an upturn in its market occupation and total industrial size.

4. Industrial Outlook for China and the US PV Cell Industry

4.1. China's Industrial Outlook in the PV Cell Industry

China's dominance in PV cell production is expected to continue, driven by its relentless focus on scaling up manufacturing capacity, investing in research and development, and expanding its presence in international markets. The Chinese government's commitment to renewable energy and its ambitious targets for solar deployment provides a strong foundation for sustained growth in the industry.

One of the key opportunities for China lies in its efforts to consolidate the fragmented solar manufacturing sector, addressing issues such as overcapacity and quality control. By streamlining production processes, optimizing supply chains, and fostering collaboration between industry stakeholders, China can enhance efficiency and competitiveness in PV cell production. China poses a special advantage as China's economic system allows direct government intervention and could thus greatly hasten up the previous process. In contrast, while companies in the US could also go through the streamlined process, its speed would be greatly hindered due to a lack of coordination and internal competition.

Furthermore, China's Belt and Road Initiative presents significant opportunities for the country to export its solar technology and expertise to emerging markets, thereby expanding its global footprint in the renewable energy sector. Current Chinese investment in foreign PV industry, especially the ones in ASEAN and India, would present itself as both a geopolitical and economic asset in the future.

However, geopolitical tensions, trade barriers, and scrutiny over human rights issues could pose challenges to China's ambitions for international expansion. With the ever-growing geopolitical tension and heightened trade protectionism in Europe and India, the export and distribution of China-made PV cells could prove to be the major choke point as the 45% tariff currently imposed on Chinese PV panels is expected to increase in the future [11, 12]. China's trend in industrial export is expected to decrease and even grind to a halt, while overseas industrial investment would be more prevalent in China, shifting the production center from China to ASEAN countries and India.

4.2. US Industrial Outlook in PV Cell Industry

In the US, the PV cell production industry is poised for growth, driven by a combination of technological innovation, supportive policies, and increasing consumer demand for clean energy. The country's vibrant ecosystem of research institutions, start-ups, and established companies fosters a culture of innovation, driving advancements in solar technology and manufacturing processes.

One of the key opportunities for the US lies in harnessing emerging technologies such as perovskite solar cells, tandem solar cells, and thin-film technologies (NREL) to improve the efficiency and cost-effectiveness of PV cell production as the considerable amount of investment into both industrial-based research and frontier research independent from the business (SEIA) could end up in game-changing technology and overturn the disadvantage currently faced by the US PV cells industry. The major downside is that no definitive conclusion could be drawn from the current progress of frontier research and that there was no definitive time or assured quality of the breakthrough, thus making the reliance on frontier breakthrough unreliable and improbable. Also, other countries could adopt the newer technology within a few years due to globalization making technological discreteness impossible (SEIA), and the previously mentioned problem in the US industry would still exist, causing the US to lose its advantage once other countries had adapted it.

Additionally, investments in workforce development and infrastructure can further strengthen the domestic solar manufacturing base, creating jobs and driving economic growth. The Biden administration and the previous Trump administration focused on rebuilding the US industrial capabilities to face the geopolitical threat China had posed (SEIA). The reconstruction of US industrial capabilities would help the PV sector to overcome the multiple issues it currently faces in the US, including a functional supply chain that wouldn't rely on imports, a cheaper transportation system, a lower labor price, or a decrease in labor reliance and full-scale government support (SEIA). These improvements could help US manufacturers overcome the competitive disadvantage they had against Chinese manufacturers on some scale, though not entirely.

The geopolitical tension would also favor US manufacturers, as Western countries would be likely to engage in further trade wars and impose more protective tariffs to counter the Chinese dominance in the world market. The current protective tariff imposed on Chinese PV cells would be vital for the development of the US PV cell industry as they are currently inferior to their Chinese counterparts (SEIA). Similar developments were also expected in other Western countries, thus opening up their market to be free from Chinese competition.

However, the US faces challenges such as competition from overseas manufacturers, particularly from China, which benefits from economies of scale and government support. Supply chain vulnerabilities, highlighted by disruptions caused by the COVID-19 pandemic, underscore the importance of diversification and resilience in the solar industry (NREL). Also, the uncertainty from governmental changes, especially a change of president, would be expected to be a major variable and uncertainty as the 2 different candidates have wildly different ideals on reindustrialization of the US.

Policy uncertainty, including changes in tax incentives, trade policies, and regulatory frameworks, also poses a risk to the growth of the US solar industry. Continued support from federal and state governments, along with bipartisan efforts to address climate change, will be crucial in providing stability and certainty for investors and industry stakeholders.

5. Suggestions

5.1. Solutions for Problems in China's Industrial Outlook

The future of China's PV industry was rather grim, according to previous analyses, as it was mostly endangered by ever-mounting geopolitical tensions and the corresponding protective tariffs. Thus, the best way for China to maintain its global dominance is to search for ways to bypass or prevent

the protective tariff being levied on PV products from China. There were 2 main ways for this, namely outsourcing production to other countries and establishing geopolitical alliances to prevent the tariff in the first place. Both of the methods have been practiced in other industries in China but not yet in the PV industry.

Outsourcing production was the major way of bypassing the protective tariffs. Since most of these tariffs were only put on Chinese products, changing a country of production would easily solve the issue. Currently, a considerable number of Chinese production companies, mostly with low technological requirement industries (i.e., cloth production), have established foreign factories that range from simply relabeling the products imported from their home countries to completing independent production. For the PV industry, the main obstacle in outsourcing production is not with price consideration or even any form of economic consideration but from government pressure. The Chinese government has put a heavy hand in restricting the most advanced technology, which is outflowing to other countries through production outsourcing. This then only allows the PV industry to set up "relabeling factory" abroad, but even this practice has been threatened by the harshed import inspection system aimed at countering the relabeling practice, with a requirement of a certain percentage of the component being produced domestically in the importing countries.

The other way is to prevent tariffs through geopolitical maneuvers. This strategy has been practiced under the "Belt and Road" initiative since 2015, where economic alliance and softening of geopolitical hostilities allow Chinese products to enter the target market without much resistance, such as tariffs or quotas. The strategy has seen some success in the past, especially with ASEAN countries and central Asia countries. But as geopolitical tension has risen in recent years, the geopolitical atmosphere around China has been quickly deteriorating, thus resulting in the general failure of China to further its geopolitical alignment, along with the halting of PV industry expansion through this method.

5.2. Solutions for Problems in the US Industrial Outlook

The greatest problem for the US PV industry is its rather incompetent production system compared to its rival, China. The long years of deindustrialization left the US industry in ruins since 2008, and thus, they were unable to create a competitive industry to counter foreign economic expansion in the US market and would have to resort to the implementation of sanctions and tariffs. Thus, the best solution is to strengthen industrial capacity through the use of industrial subsidies and government interference in the formation of the industry.

Industrial subsidies and similar production initiatives have already been implemented during the Biden administration, and since then, positive feedback has been seen from the market. To the PV industries, the current subsidies may serve as a major contribution factor for the future development of the market, mainly in the effort to provide more financial backbone to the currently small in scale US PV industry and, in turn, allow the enterprises in the industry to make more radical investment to boost up the production. The method, like all other methods for the industry, comes with a backlash. The reliance on financial support from the government may result in considerable draining of the government budget and, in turn, harm the economy elsewhere in the country, considering the current financial deficit the US government has. Also, such reliance on subsidies may result in a lack of competitiveness as the companies enjoy the protection of tariffs and subsidies for too long, resulting in a loss of international competitiveness.

The second possible solution is direct government interference in the formation of the industry. As the natural formation of a sufficient supply chain along with a stable industrial system and transport system would cause a rather long period of time, the US government could directly intervene in the formation of the said system and quickly build up an industrial system in the PV panel industry that could rival most other countries, and in turn, China. The method of intervention could vary from direct funding toward companies with the potential to the construction of a concentrated industrial facility to minimize the transportation cost, mimicking their Chinese counterpart. The problem with

this method was also obvious, as direct interference with the market economy is a direct violation of the social and economic norms in the US and may result in a counteract from the market, hindering or even halting the progress made in the industry.

6. Conclusion

In conclusion, the paper has introduced and made a brief analysis of the current status and industrial outlook for the PV industry, and thus, in turn, listed some possible solutions for the problems analyzed in the industrial outlook section. This research was focused on this field to raise awareness of the current situation of the PV industry, which, as previously mentioned, serves as an important part of modern environmental protection and the transition to renewable energy. Also, the paper has provided possible predictions on governmental action in the future, which may provide a certain degree of information for the players within the industry.

Lastly, this paper has various limitations, such as basing on secondary resources, lacking direct surveys and interviews from the market, and a speculative approach to governmental policy examination without any first-hand information. However, such also provided possibilities for further improvement, such as conducting interviews with players in the industry for first-hand information or accessing other first-hand data for further evaluation of the topic.

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