China's New Energy Industry: Key Characteristics and Competitive Advantages

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Abstract: *In recent years, China's burgeoning exports of "new three" products have led some Western media outlets and politicians to falsely claim that China is experiencing overcapacity in the new energy sector. These entities and individuals have advocated for countervailing investigations into China's new energy products, increased tariffs, and other anti-free trade measures. To address such unfounded criticisms, we have outlined three major contributions of China's new energy industry to the world. Building upon a summary of the three evolving characteristics and seven competitive strengths of the industry, we present policy recommendations for the high-quality development of China's new energy industry. Our findings provide a factual basis to refute the unfounded claims of certain Western countries.*

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1. Introduction

In recent years, China's new energy products have gained significant global traction. China has maintained its leading position in photovoltaic component manufacturing for 16 consecutive years, accounting for over 80% of global output and capacity in polycrystalline silicon, silicon wafers, and solar cells (Zhang, 2024). China's new energy vehicle (NEV) industry has rapidly evolved from a follower to a global leader. In 2023, Chinese NEVs captured a global market share of 65%-68%, and this figure is projected to exceed 70% by 2025. According to General Customs Administration data, China's combined exports of NEVs, lithium-ion batteries, and photovoltaic products[1] surpassed one trillion yuan for the first time in 2023 (Lin, 2024).

However, some Western media outlets and politicians have frequently invoked the "overcapacity" argument to impede China's NEV development. US Treasury Secretary Janet Yellen repeatedly cited "overcapacity" in China's new energy industry. In May 2024, the US government significantly increased tariffs on Chinese electric vehicles(EVs), photovoltaic products, and lithium-ion batteries to 100%, 50%, and 25%, respectively, on the basis of the existing Section 301 tariffs. Despite the absence of an industry

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[1] In this paper, new energy vehicles mainly refers to electric vehicles (EVs), photovoltaic products mainly refers to solar panels.

petition, the European Commission (EC) initiated a countervailing investigation into Chinese EVs. The EC meticulously documented information about each EV model sold in Europe to justify potential penalties. Additionally, the EC launched countervailing investigations into Chinese photovoltaic enterprises under the *Foreign Subsidies Regulation* (FSR).

Undeniably, these accusations are unfounded and inconsistent with factual evidence. The practices of countervailing investigations and tariff increases contravene the principles of free trade and could hinder global energy transition efforts. Such accusations stem from a misunderstanding of China's new energy industry's global contributions, development trajectory, and product competitiveness. Previous academic research has focused on the development characteristics of China's new energy industry (Chen et al., 2022; Hu, 2022; Li, 2024), competitive strengths (Han, 2024; Li, 2023; Liu, 2024; Yang and Song, 2024), and strategies to address trade barriers (Guo and Li, 2024; Duan, 2015). However, there is a dearth of systematic research on the competitive strengths of China's "new three" exports, limiting effective responses to concerns raised by certain countries regarding China's new energy industrial competitiveness. This paper aims to address this gap by identifying China's new energy industry's threefold global contributions and seven competitive advantages. Finally, we propose strategic recommendations for the high-quality development of China's new energy industry.

2. China's Role in Accelerating Global Energy Transition

New energy, with its widespread availability, high potential, and low-carbon, environmentally friendly characteristics, has become a crucial solution for countries addressing climate change. To conserve energy, reduce emissions, and achieve carbon peak and neutrality goals, the Chinese government has made substantial investments in the new energy industry, particularly in NEVs, lithium-ion batteries, and photovoltaic power. This strategic approach is vital for both China and the global community.

2.1 China's New Energy Industry: Driving Global Carbon Reduction

As global climate change and environmental protection become increasingly pressing international concerns, all nations face the significant challenge of mitigating climate change by reducing CO_2 emissions (Fan et al., 2024). China, as the world's largest carbon emitter, faces considerable pressure to ensure its economic sustainability due to its coal-dominated energy mix. In response, China is committed to accelerating energy transition and developing the new energy industry as a key strategy to fulfill its international obligations and reduce carbon emissions.

Second, China's carbon emissions account for one-third of global total. Its development of new energy to replace coal and other fossil fuels will directly help reduce the total global carbon emissions. In 2022, China's substantial increase in renewable energy-based power generation reduced CO_2 emissions by 2.26 billion tons (Ye, 2024), making a significant contribution to global carbon emission reduction efforts.

Third, China's "new three" exports have contributed to global energy conservation and reduced carbon emissions in other countries. China's exports of wind and photovoltaic products are estimated to have helped other countries reduce CO2 emissions by 573 million tons, accounting for 41% of global emissions reductions from renewable energy sources (Ye, 2024).

Consequently, China is the largest contributor to global renewable energy development (Dong, 2024). China's new energy industry has not only reduced carbon emissions for itself, but also indirectly

reduced carbon emissions in other countries, providing critical support for meeting global temperature control targets.

2.2 China's Trade in New Energy Products: Driving Global Economic Growth and Industrial Chain Collaboration

First, China's new energy industry is driving global trade by meeting the surging demand for clean energy solutions. China's leadership in NEVs, lithium-ion batteries, and solar cells has provided countries worldwide with a wealth of clean energy options. For instance, Chinese solar cell manufacturers have established numerous factories in Southeast Asia, Africa, and other regions, not only meeting local energy needs but also generating jobs and stimulating local economic development. Similarly, Chinese electric vehicle (EV) manufacturers have set up factories and R&D centers in Europe, Southeast Asia, and elsewhere, fostering partnerships with local companies and accelerating global EV industry development. China's "new three" energy products have emerged as a new engine of global economic growth due to their high value-added, rapid growth, and extensive market potential. The export of new energy products not only promotes the prosperity of international trade but also strengthens economic cooperation. It also injects new vitality into global integration and accelerates the recovery and growth of the world economy.

Second, China's new energy trade fosters global industrial chain cooperation. China has forged strong partnerships with numerous countries and regions to advance new energy development. This cooperation extends beyond goods trade to encompass technology R&D, industrial chain consolidation, and market exploration. By collaborating closely with international partners, Chinese new energy enterprises have accelerated their integration into global industrial chains, enhancing their international competitiveness. Such cooperation also significantly supports the coordinated development of the global new energy industry, driving overall industry growth.

The global expansion of China's new energy enterprises has accelerated the globalization of the new energy industry, leading to the optimal allocation and sharing of global resources. Such industrial optimization and restructuring has enhanced the competitiveness of the global new energy industry, ultimately contributing to global economic sustainability.

2.3 China's New Energy Products: Catalysts for Global Technological Leaps and Collaborative Innovation

Fueled by global technological competition and sustainable development goals, China's innovative new energy products have not only met the urgent global demand for clean energy but have also played a pivotal role in advancing global technological progress and fostering international innovation cooperation.

Thanks to relentless technological innovation, China's new energy sector has rapidly transformed from obscurity to prosperity in a few decades. From improving the electro-optical efficiency of photovoltaic cells to advancing the intelligent operation and maintenance of wind power equipment, and from breakthroughs in NEV battery technology to R&D for autonomous driving systems, China has consistently set new industry standards. These technological advancements have not only enhanced the global competitiveness of China's new energy products but have also established a benchmark for global new energy technology development, contributing to the shaping of the industry's development trajectory.

China's substantial investments in new energy have generated significant technological spillover

effects (Chen and Xian, 2020). As the adoption of Chinese new energy products increases globally, international companies and research institutions have begun to closely monitor and participate in China's new energy technological exchanges and collaborations. These exchanges and collaborations have not only facilitated the dissemination and sharing of technology and knowledge but have also sparked new ideas and opportunities for international innovation partnerships. For example, Chinese new energy enterprises have partnered with international research institutions to address technological challenges while simultaneously learning from advanced technologies and management practices. Such two-way exchange and collaboration have led to significant advancements in new energy technologies and innovations.

3. China's Transformative New Energy Industry Trajectory

3.1 Moving towards a Sophisticated Stage of Development

China's new energy industry has evolved through the nascent and rapid growth phases of the global energy transition, and now stands at a sophisticated stage of development.

Embryonic stage (1950s-1999): Faced with the challenge of energy scarcity, China began to explore new energy technologies such as small hydropower and biogas digesters. However, constrained by immature technology, low market awareness, and incomplete supply chain, the development of the new energy industry has been slow and fragmented. New energy technologies were still in the initial stages of research and development, primarily applied to small-scale, local projects.

Rapid growth stage (2010-2017): The growing global emphasis on a low-carbon economy, coupled with China's commitment to reducing carbon emissions, accelerated the development of the new energy industry. Technological advancements and supportive policies fueled rapid growth in solar and wind power capacities, expanding the markets for power batteries and NEVs. As shown in Figure 1, China's installed wind capacity surged from 29.58 GW to 163.25 GW, representing a 451.89% increase, while installed photovoltaic capacity grew from nearly zero in 2010 to 129.42 GW in 2017. China's installed power battery capacity increased from 0.8 GWh in 2013 to 36.24 GWh in 2017, and NEV sales rose from 75,000 units in 2014 to 777,000 units in 2017. During this period, China's new energy industry experienced rapid expansion despite intense competition. Companies gained competitive advantages through technological innovation and efficiency improvements. As market concentration increased, industry barriers began to emerge.

Mature development stage (2018–present): As China's new energy industry entered a mature development stage, growth rates slowed and market saturation increased, shifting the competitive focus toward efficiency and profitability improvements. Aligned with the nation's carbon peak and neutrality goals, the NEV industry experienced significant growth, driven by increased policy support, the rise of intelligent connected vehicles (ICVs), and accelerated construction of charging and energy storage infrastructure. Figure 1 illustrates that installed wind power capacity increased from 184.27 GW in 2018 to 365.64 GW in 2023, while photovoltaic power capacity grew from 174.33 GW to 392.68 GW over the same period. Installed power battery capacity surged from 56.89 GWh in 2018 to 387.7 GWh in 2023, and NEV sales climbed from 1.256 million units in 2018 to 9 million by 2023. Companies like CATL and BYD have introduced numerous innovative technologies, significantly enhancing their global competitiveness. Despite ongoing challenges related to battery range and stability, Chinese companies have increased R&D investment and market consolidation, signaling strong growth potential in this mature stage.

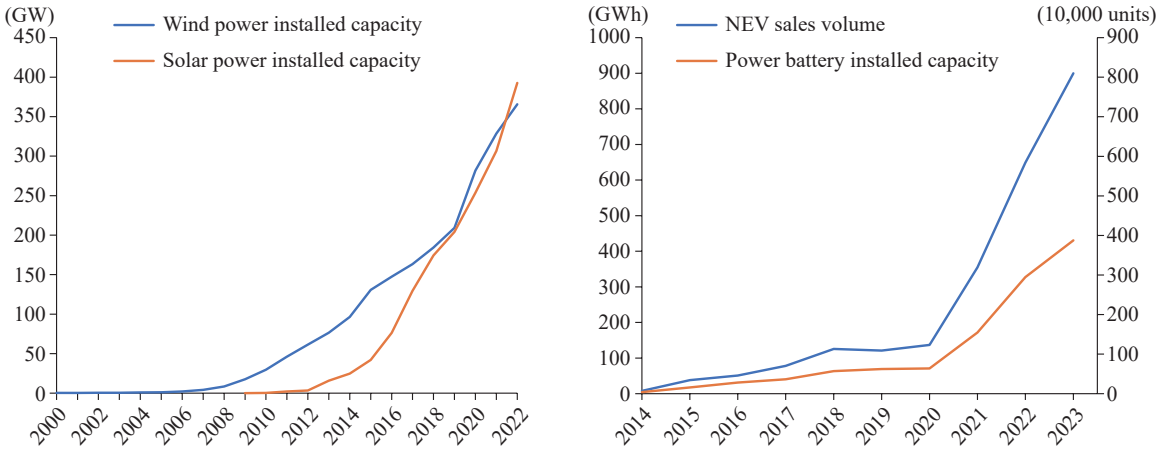

Figure 1: Change in Sales of Chinese New Energy Products

Source: Calculated based on *China Statistical Yearbook* of various years.

3.2 Continuously Strengthening Market Mechanisms

During the initial and rapid development stages, the government provided essential policy support and legal frameworks to address critical challenges, laying the foundation for the new energy industry. For instance, the government issued a series of plans (such as the *New Energy and Renewable Energy Industry Development Plan* in 2000 and the *Mid-and Long-term Renewable Energy Plan* in 2006) and decisions (such as the *Decisions on Fostering Strategic Emerging Industries* in 2010). These policy documents outlined clear industrial development directions, increased support for key industries, and established a robust service system to promote industrial growth. The Chinese government has continuously improved its legal framework to support the development of the new energy industry, enacting the *Clean Production Promotion Law* and the *Renewable Energy Law*, along with their amendments. These laws and regulations effectively promoted new energy development by providing legal safeguards for renewable energy power generation and grid connection, such as the guaranteed purchase of all renewable electricity and the establishment of a dedicated new energy development fund.

To adapt to the increasing sophistication of the industry and evolving market dynamics, the Chinese government has transitioned towards market-based mechanisms to stimulate competition in the renewable energy sector. This policy shift aims to drive industrial transformation and upgrade. Market-based electricity power reform, a green electricity trading system, and a renewable energy power quota system are key examples of these policy initiatives. Electricity market reform has laid the foundation for the new energy market. Since the implementation of the *Power Sector Institutional Reform Plan* in 2002, China's power industry has steadily progressed towards market-based operations. The 2015 *Opinions on Deepening Power Sector Reforms* outlined a path of "three liberalizations, one independence, and three strengthenings", further accelerating market-oriented reforms. In recent years, the Chinese government has intensified efforts to establish a multi-tiered and unified power market, actively developing a national power market. A series of guidelines and circulars have been issued to unify and open the power market, expanding market opportunities for new energy power. In 2017, the National Development and Reform Commission (NDRC), the Ministry of Finance, and the National Energy Administration (NEA) jointly issued the *Circular on the Pilot Issuance of Renewable-based Green Power Certificates and the Voluntary Subscription and Transaction System*. The

official launch of the green certificate subscription system on July 1, 2017, expanded funding sources for new energy projects. Subsequent policies, such as the *Circular on Promoting the Full Coverage of Renewables-based Green Power Certificate for the Promotion of Renewables-based Electric Power Consumption* and the *Circular on Enhancing the Linkage between Green Power Certificate and Energy Conservation and Carbon Emissions Reduction Policy for the Promotion of Non-fossil Energy Consumption*, further refined the green power certificate trading system. This market-based green certificate and quota system has effectively facilitated the consumption of new energy power, leading to a steady increase in clean energy transactions. In 2021, China's market-based clean energy consumption reached 721,500 GWh (Liu, 2022).

3.3 Continuously Enhancing Endogenous Growth

In its early stages, China's new energy industry faced significant challenges, including high costs, immature technology, and weak market competitiveness. To address these challenges, the government actively supported the new energy industry through fiscal subsidies and tax breaks. Similar to the European Union's REPowerEU Plan and the *American Recovery and Reinvestment Act of 2009*, which provided substantial government support for the new energy sector, China implemented the *Renewable Energy Law in 2005*. This law effectively reduced the cost of new energy power generation and increased market competitiveness through electricity tariff subsidies, quota transactions, and other policy instruments. In addition to accelerating new energy development, these policies laid the foundation for future technological advancement and cost reduction.

Technological advancements and emergence of economies of scale have led to a significant reduction in new energy costs. For instance, in photovoltaic power generation, technological improvements have increased component efficiency while substantially reducing manufacturing costs. As industrial chains mature and market mechanisms take hold, photovoltaic power generation projects have become increasingly profitable, attracting substantial private investment. These developments have enabled photovoltaic power generation to achieve grid parity. In 2018, the NDRC, the Ministry of Finance, and the National Energy Administration (NEA) issued a policy document aimed at refining the photovoltaic electricity tariff mechanism, reducing subsidy intensity, and encouraging local governments to develop photovoltaic industrial policies and implement subsidy-free projects. Fiscal subsidies were phased out on January 1, 2021, as market-based allocation and policy improvements took effect. Since then, the feed-in tariff for centralized photovoltaic power plants has aligned with the local baseline tariff for coal-fired power generation. As of 2022, neither centralized nor distributed photovoltaic projects have received any central fiscal subsidies.

As China's power market reforms deepen and the cost of photovoltaic (PV) power generation declines rapidly, Chinese PV power has achieved grid parity—or even at lower costs. This demonstrates that China's new energy sector possesses a robust capacity for self-development, allowing it to swiftly adapt to shifting market conditions and thereby enhance market competitiveness.

4. China's New Energy Industry: Competitive Strengths

China's new energy industry is a cornerstone of the country's strategic emerging industries, providing a pathway toward a green energy transition. Over the past decade, China has emerged as a global leader in the new energy sector. China's "new three" energy products have gained global popularity due to their competitive pricing and advanced technological content.

4.1 Abundant Mineral Resources for New Energy Development

China's rapid new energy development is underpinned by its abundant mineral resources and favorable geological mineral-forming conditions. These resources provide low-cost raw materials for the manufacturing of "new three" products, ensuring a stable supply of materials for both upstream and downstream new energy industrial chains.

First, polycrystalline silicon resources. China is the world's largest producer of polycrystalline silicon, a key material in the photovoltaic industry. Progress in photovoltaic technology and the accelerating global energy transition have led to a rapid increase in China's polycrystalline production, which reached 1.472 million tons in 2023, representing a 71.8% annual increase[2]. With low electricity costs and favorable production conditions, Xinjiang, Inner Mongolia, and Sichuan have emerged as primary polycrystalline silicon manufacturing sites, underpinning China's dominant position in global PV industrial chains.

Second, rare-earth resources. Rare earths are critical materials in the NEV industry for making high-performance electric motors, batteries, and catalysts. China has the world's largest rare-earth reserves, totaling 44 million tons and accounting for 44% of global reserves. More importantly, China has established a complete industrial chain for rare earth exploration, extraction, and application, as well as processing technology and supply capabilities for the vast majority of rare-earth resources worldwide[3].

Third, quartz and graphite resources. Quartz is a key raw material in the photovoltaic and electronics industries. China's verified high-grade quartz reserves exceed 14 billion tons, enough to supply relevant industries with stable raw materials. China has the world's largest graphite reserves, totaling 78 million tons, accounting for 27.86% of global reserves[4]. Graphite has numerous applications, including lithium-ion batteries and graphene-based new materials. Abundant reserves and high mineral quality have paved the way for rapid development in China's new energy and materials industries.

Fourth, lithium mineral resources. The abundance of lithium mineral resources as critical raw materials for NEV and energy storage technologies is critical to China's new energy industry. The lithium triangle in South America, which includes Bolivia, Chile, and Argentina, contains the world's largest lithium ore reserves. Chile has the most lithium ore reserves in the world, accounting for 35.78% of the total. China also has a relative abundance of lithium ore reserves, ranking fourth globally[5]. China's lithium ore reserves are spread across a wide geographical area, from salt lakes in the south of Qinghai Province to mineral deposits in Sichuan Province. The relative abundance of lithium-ore resources provides strong support for China's rapid NEV development.

4.2 Ultra-Large Market Advantage: Leveraging NEV Economies of Scale

China has an ultra-large market advantage as the second-largest economy in the world. This unique condition creates a large space and enormous potential for rapid "new three" development. This market advantage is reflected not only in a large consumer group with diverse needs, but also in its ability to unleash technological innovation, promote industrial upgrading, and foster internationally competitive

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[4] Chinabaogao.com: China's Natural Graphite Industry: Navigating Rising Market Thresholds with Expanding Output Amid Shrinking Exports, https: //www.chinabaogao.com/market/202409/728169.html.

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industrial clusters.

First, the ultra-large market provides fertile ground for the development and promotion of new technologies and products. Because of its larger population and multitiered consumer requirements, the Chinese market is very open to new technologies and has a high demand for new products. This has prompted businesses to invest in R&D and create high-end, intelligent, and environmentally friendly products to meet market demand. As a symbol of China's advanced manufacturing, the "new three" have gained consumer recognition for their technological innovation and competitive advantages.

Second, significant economies of scale have assisted businesses in lowering costs and increasing competitiveness. China's ultra-large market scale allows "new three" enterprises to profit through mass manufacturing and sales, which offsets the high upfront fixed and innovation costs (Zhou, 2024). While assisting Chinese companies in dominating the domestic market, such a cost advantage also allows them to enter the international market and become more competitive. Furthermore, economies of scale facilitated improvements to industrial chains, resulting in a benign ecosystem of coordinated upstream and downstream development.

Third, the ultra-large market allows for competition and growth across multiple technology paths. In the "new three" sector, technological innovations are critical driving forces of industrial development. China's market is large enough to support competing technology paths. Consider lithium-ion batteries: the market offers both high-energy-intensity products such as ternary lithium batteries and better value-for-money options such as lithium iron phosphate batteries. A diverse competitive landscape encourages technological innovation and industrial upgrading while also providing consumers with a variety of options.

Fourth, the ultra-large market has a significant appeal and influence on global industrial chains. China's thriving "new three" industries have prompted international corporations to focus their attention on the Chinese market and seek opportunities for collaboration. This has strengthened China's integration and cooperation with the international market, increasing its position and influence in global industrial chains.

4.3 Natural Advantage: Geographical Factors for New Energy Development

The nascent new energy industry is highly dependent on specific geographical conditions, demanding exceptional resource efficiency and environmental compatibility. In this regard, China possesses unique advantages that position it favorably for the development of new energy technologies.

First, China's vast territory spans multiple climate zones, and the diverse geographical environment provides new energy projects with a wide range of application scenarios. Photovoltaic power generation, as a key new energy component, has extremely high requirements for sunlight. Most parts of China, particularly the central and western regions, have long annual sunshine periods and strong solar radiation. Over two-thirds of China's land area has annual sunshine durations of at least 5,000 megajoules per square meter, providing ideal natural conditions for photovoltaic power plants. Sufficient sunlight resources have made photovoltaic power generation more affordable and profitable, allowing solar power to play an important role in China's new energy industry.

Second, China has abundant wind energy resources, and they are widely distributed. Its northeastern, northern, and northwest regions are ideal for building large wind farms due to their flat terrain and strong, consistent winds. Furthermore, the coastal areas also possess abundant wind energy resources. Thanks to the maritime climate and topographical features, the wind resources in coastal regions have great potential for development. Abundant wind resources provide support to wind power development

while helping to promote the diversification and low-carbon transition of the energy structure.

Any new energy project, whether photovoltaic or wind power, can be implemented in China with proper development and widespread application. While backing up China's new energy industry development, these natural advantages open up new avenues and platforms for global new energy industry collaboration and exchange.

4.4 Human Capital Advantage: Strengthening Intellectual Support for the New Energy Industry

With the profound changes in the global economic landscape and industrial transition and upgrade, China's economic development has gradually shifted from relying on the exports of "old three" exports, i.e., apparels, home appliances, and furniture, to a high-quality development stage represented by new energy vehicles, photovoltaic products, and lithium-ion batteries, known as the "new three." In this transition, highly qualified professionals provide the driving force and intellectual support for the "new three" to thrive.

First, cultivating top-tier R&D talent. The core competitiveness of the "new three" is based on technological innovation and R&D capacity. In recent years, China has increased its investment in higher education and research institutions, as well as trained a large number of R&D personnel with an international perspective, innovative spirit, and specialized skills. These top professionals have made significant advances in new energy technology, photovoltaic material science, and battery management systems, among other critical areas. They provide the "new three" industries with unwavering innovation dynamism, assisting in product performance enhancement and production cost control.

Second, recruiting a robust workforce of skilled labor. Beyond top talent, the new energy industry requires a skilled workforce. China boasts a large pool of skilled workers with increasing levels of expertise. In intelligent manufacturing and automated production lines, China's extensive use of skilled labor has enhanced production efficiency and ensured consistent product quality. Additionally, China has invested in continuous workforce development through vocational training and re-education programs, fostering a strong human capital foundation for the growth of the "new three" industries

Third, enhancing educational systems and support. By continuously improving its educational system, China can ensure a long-term supply of talent to fuel the development of the "new three industries." From primary education to higher education, vocational training, and lifelong learning, China has established a comprehensive and well-structured educational framework. In recent years, the Chinese government has prioritized aligning vocational education with industrial demands and fostering partnerships between universities and businesses to cultivate highly skilled talent who can meet the evolving needs of the market.

Fourth, strengthening policy support and incentives. The Chinese government has implemented a series of talent policies, including talent acquisition programs, research funding, and innovation incentives, to further stimulate innovation and entrepreneurship. Additionally, efforts have been made to streamline regulatory formalities and improve the business environment, providing "new three" enterprises with efficient services and attracting top talent from both domestic and international markets.

4.5 Innovation-Driven: Increasing Technology Content of New Energy Products

The "new three" sectors have significantly contributed to enhancing product energy efficiency and reliability by rapidly adopting the latest research and development breakthroughs. A high technological content is crucial for the global competitiveness of China's "new three" energy products. China has demonstrated substantial technological leadership in the new energy industry, particularly in the following key areas:

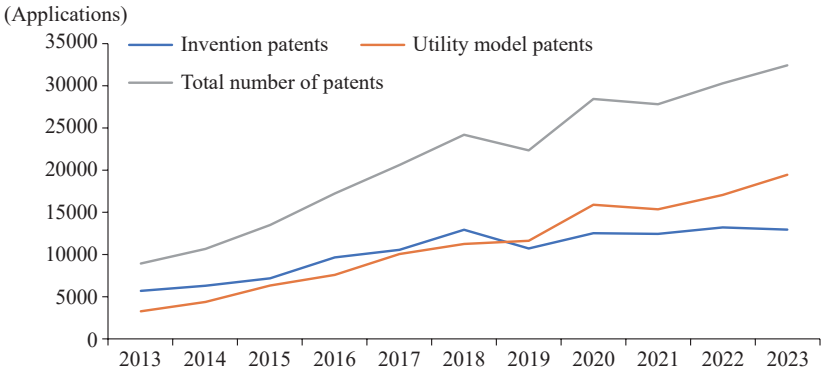

Figure 2: Growth in China's Photovoltaic Patent Filings, 2013-2023
Source: The Chinese National Patent Database, compiled by the authors.

First, battery technology. China has made significant strides in electric vehicle battery technology. Companies like CATL have achieved world-class levels in battery energy density, safety, and cycle life. Moreover, rapid advancements in emerging energy storage technologies, such as solid-state batteries, are poised to further revolutionize EV performance.

Second, vehicle technology. EV manufacturers, spearheaded by BYD and Tesla (Shanghai Gigafactory), have accelerated EV market growth through their innovative vehicle designs, efficient manufacturing processes, and advanced intelligent features.

Third, photovoltaic technology. China boasts a comprehensive photovoltaic industry chain and robust technological capabilities. As depicted in Figure 2, China's photovoltaic-related patent filings surged between 2013 and 2023. Notably, China's invention patent filings nearly quadrupled in a decade, from 8,903 to 32,443, significantly outpacing those of the European Union and the United States. Companies such as LONGi Green Energy have achieved significant breakthroughs in improving solar cell conversion efficiency, reaching world-class levels in both mono-crystalline silicon single-junction cells and crystalline silicon-perovskite tandem cells.

Fourth, photovoltaic power system integration. China has made significant strides in integrating photovoltaic systems with other energy systems, enhancing energy utilization efficiency and system stability.

4.6 Boosting New Energy Productivity: Complete Industrial and Supply Chains

In today's globally interconnected economy, the completeness of a nation's industrial and supply chain has emerged as a critical determinant of its manufacturing competitiveness. China stands alone as the only country encompassing all industrial sectors recognized by the United Nations classification. It ranks number one in the production of over 220 industrial products and has held the top position in global manufacturing capacity for 13 consecutive years. This comprehensive industrial system has enabled China to achieve substantial independence in the manufacturing of new energy products. For example, BYD produces its proprietary components, including batteries, electric motors, electronic systems, and radar, while Tesla's Shanghai Gigafactory focuses on vehicle assembly. Complete industrial and supply chains are instrumental in streamlining procurement, optimizing the distribution of raw materials and components, and consequently, reducing costs and boosting production efficiency. The combination of mass production and technological innovation has further contributed to cost reduction

and enhanced competitiveness.

First, complete industrial chain advantage. China possesses a complete industrial chain spanning from raw materials to end products and services, encompassing research and development, design, manufacturing, marketing, and after-sales services. This comprehensive industrial advantage has streamlined operations, reduced costs, and enhanced efficiency and synergy between upstream and downstream enterprises, enabling rapid response to market demands. Notably, in the New Energy Vehicle (NEV) sector, China has developed a robust industrial ecosystem that includes core components, vehicle manufacturing, and services.

Second, strong industrial clustering effects. China has actively promoted clustered industrial development to foster efficient coordination within industrial and supply chains, resulting in the formation of a series of globally competitive industrial clusters through regional cooperation and resource integration. For instance, the Yangtze River Delta region has emerged as a significant hub for the NEV industry. Hefei City in Anhui Province, a key NEV center, hosts a diverse range of automakers. This region has established a robust supply assurance system, encompassing vehicle assembly in Anhui, chip and software R&D in Shanghai, power battery manufacturing in Jiangsu, and integrated bodywork die-casting molds in Zhejiang, creating a "four-hour industrial circle" for new energy enterprises. Inter-regional cooperation has facilitated the seamless flow of technology, talent, capital, and other production factors, accelerating the deep integration between upstream and downstream enterprises and forming an efficient and coordinated supply chain system.

Third, innovation-driven industrial upgrading. China has consistently prioritized innovation as the primary driver of industrial and supply chain improvement. By significantly increasing R&D investment and accelerating technological innovation and industrial upgrading, China has significantly enhanced the core competitiveness of its industrial chains. In the NEV sector, Chinese enterprises have achieved groundbreaking technological advancements in power batteries, electric motors, and electronic control systems, breaking foreign technological monopolies and successfully exporting to international markets. Furthermore, rapid progress in cutting-edge technologies such as intelligent connected vehicles (ICVs) and autonomous driving has infused new vitality into the NEV industry, propelling further industrial chain upgrading.

Fourth, supply chain resilience for the global market. China's industrial and supply chains have demonstrated remarkable resilience in navigating the complex and volatile international landscape. Through diversified distribution channels and globalized partnerships, Chinese enterprises have proactively expanded their global market presence and increased market share while safeguarding supply chain stability. Particularly in the NEV sector, Chinese enterprises have garnered significant international acclaim for their advanced technologies, high-quality products, and comprehensive after-sales service systems, contributing to the global sustainable development of the NEV industry.

4.7 Government Guidance for Orderly NEV Development

The Chinese government has implemented a series of targeted policies and strategic planning to cultivate a vibrant, sustainable, and well-regulated market environment, thereby promoting the healthy development of "new three" products and the high-quality growth of the NEV industry.

First, defining strategic direction and formulating long-term plans. The central government has enacted a series of strategic plans and policy documents to provide clear guidance and robust support for the development of "new three" industries, including the *NEV Industry Development Plan (2021-2035)*

and the *Opinions of the State Council on Promoting the Sound Development of the Photovoltaic Industry*. These documents have established key performance indicators for market size, technological innovation, industrial chain improvement, and international competitiveness. Detailed industrial development plans have been developed for each market segment, outlining clear development paths, priorities, and policy initiatives to ensure steady and orderly industrial growth.

Second, offering the Chinese solution for the global energy transition. Amidst the profound global energy transition, Chinese new energy enterprises are encouraged to intensify technical exchanges and cooperation with leading international companies to drive key technological breakthroughs and upgrades. Chinese new energy enterprises are supported in delivering cost-effective new energy products to the global market, providing clean and efficient energy solutions to all nations while enhancing economic sustainability and improving people's lives.

Third, optimizing industrial layout and fostering regional coordination. The "new three" industries are encouraged to develop differentiated and specialized development patterns in various regions, taking into account local resource endowments, industrial conditions, and market needs, thereby avoiding homogeneous competition. National and provincial "new three" industrial clusters have been established to facilitate close collaboration between upstream and downstream industrial chain enterprises and enhance overall competitiveness. Efforts have been made to strengthen cross-regional policy coordination, information exchange, and resource integration to create an industrial ecosystem characterized by complementary advantages and coordinated development.

Fourth, enhancing policy guidance and stimulating market dynamism. During the initial stages of industrial development, the government increased fiscal investment in the "new three" industries, reducing corporate R&D costs and operational risks through subsidies, incentives, and discounted loan interest rates. Preferential policies, such as tax breaks and weighted tax deductions for R&D spending, were implemented to incentivize R&D investment and technological innovation. As the new energy industry matured, the government promptly initiated a subsidy phase-out mechanism to optimize industrial structure and strengthen corporate competitiveness through market-driven competition.

5. Policy Recommendations for China's New Energy Sector

The rapid emergence of the "new three" industries, including New Energy Vehicles (NEVs), lithium-ion batteries, and photovoltaics, has injected significant dynamism into China's high-quality economic development. Groundbreaking innovations in these sectors have accelerated industrial upgrading and boosted competitiveness. Moreover, they have effectively mitigated greenhouse gas emissions by providing clean and efficient energy solutions, playing a crucial role in addressing climate change and promoting a green and low-carbon transition. In the context of ongoing international energy market volatility, China's new energy industry faces several challenges, including unwarranted criticism from certain countries, technological blockades of the "large yard, low fence" type, and supply chain decoupling. To address these challenges, the Chinese government must take proactive measures to enhance policy guidance, promote technological breakthroughs, and strengthen supply chains through market mechanisms, aiming to foster high-quality development of the new energy industry.

5.1 Enhancing Policy Guidance on Industrial Layout and Resource Allocation

To address the structural capacity challenges facing the new energy industry, the Chinese government must enhance top-level policy guidance and optimize industrial layout to promote efficient

resource allocation and foster high-quality new energy industry development.

First, clarifying industrial development planning and policy systems. The government should formulate mid- and long-term development plans for the new energy industry from a global perspective to establish clear development objectives, priorities, and safeguards. Industrial planning should be forward-looking, scientifically sound, and actionable to guide industrial development directions and provide stable policy expectations. To promote the coordinated development of new energy and energy storage projects, the government should leverage both policy guidance and market mechanisms to encourage the construction of integrated wind, solar, and energy storage projects. Successful cases such as the China National Nuclear Corporation's (CNNC) "Concentrated Solar Power (CSP) +" project in Yumen City should be emulated to promote the deep integration of new energy and energy storage technologies, enhancing overall energy system efficiency and stability.

Second, strengthening financial support and promoting green financial innovation. The government should enhance financial support for the new energy industry through tax incentives, fiscal subsidies, and financing guarantees. Financial institutions should be encouraged to adopt innovative "new energy plus green finance" financing models and utilize financial instruments such as equity, credit, and asset securitization to provide flexible and diverse financing solutions for green and low-carbon projects. Given the significant financing needs, market risks, limited fixed assets, and long investment payback periods of new energy enterprises, the government should collaborate with financial institutions to optimize credit policies, reduce corporate financing costs, and increase financing efficiency to ensure adequate financial support for new energy projects.

Third, establishing an industry information early warning and guidance mechanism. The government should establish a comprehensive industry information monitoring and release mechanism, leveraging modern IT tools such as big data and cloud computing to collect data on the new energy industry and stay abreast of industry trends and market dynamics. Enterprises should be provided timely access to accurate market information through the regular release of industry analysis reports, market forecasts, and policy interpretations via official websites, industry media, and social media. Additionally, capacity utilization in key sectors and enterprises should be monitored to assess excess capacity risks, issue timely early warning information, and guide enterprises in making rational investment decisions and pursuing sustainable development.

Fourth, implementing policy guidance and capacity regulation. The government should promptly introduce relevant policies for sectors and enterprises facing capacity risks. For example, it may adjust industrial policies and strengthen environmental regulations to prevent excessive competition. Additionally, it may encourage enterprises to enhance product value-added and competitiveness through technological innovation, transformation, and upgrading to foster sustainable development.

5.2 Fostering Breakthroughs in key technology and Upgrading New Energy Products

Driven by an innovation-led development strategy, China's new energy industry has ushered in a new era of intelligent and green development, demonstrating remarkable vitality and promising prospects. A comprehensive strategy, encompassing increased R&D investment, talent cultivation, and intellectual property rights (IPR) protection, is essential to propel significant technological advancements and comprehensive upgrades in key new energy technologies.

First, prioritizing innovation in critical technologies. Significant resources should be allocated to the development of critical technologies and address weaknesses in new energy intelligent manufacturing,

such as efficient battery technology, smart grid technology, and advanced energy storage technology. Establishing a dedicated fund to bolster fiscal support and financial investment for R&D projects in critical sectors and core technologies is recommended to ensure adequate resource allocation for R&D activities. China's comprehensive industrial system, vast domestic market, and strong national mobilization and organization capabilities should be fully leveraged to accelerate the commercialization of R&D results and build an independent, controllable, secure, and reliable supply chain system.

Second, deepening industry-academia-research cooperation and establishing an innovation network. To facilitate the flow and exchange of innovation factors such as technology, talent, and capital, a robust industry-academia-research cooperation network should be established. Governments, enterprises, universities, and research institutions should collaborate closely to build an integrated innovation network that promotes the exchange and flow of innovation factors. More inclusive policies should be implemented to attract top-tier R&D talent from both domestic and international sources to contribute to new energy research. Additionally, a comprehensive talent development system should be established to cultivate cross-disciplinary innovation talent and provide intellectual support for the new energy industry. Incentive mechanisms, such as rewards for R&D achievements and equity incentives, should be established and refined to unleash the innovation potential and creativity of R&D personnel and foster a continuous stream of innovation.

Third, strengthening IPR protection and enhancing international competitiveness. Greater efforts should be made to protect new energy intellectual property rights (IPRs) and establish robust IPR infringement claim, protection, and overseas dispute resolution mechanisms to provide solid legal safeguards for innovation. Measures should be taken to improve IPR commercialization, transforming innovation results into productive applications and maximizing the socio-economic benefits of IPRs. China should actively participate in the development and revision of domestic and international new energy standards, internationalize Chinese standards, and enhance the competitiveness and standard-setting influence of Chinese new energy products in the global market.

5.3 Fostering Market-Driven New Energy Development

In the early stages, the new energy industry faced challenges due to market immaturity, technological limitations, and high production costs. To accelerate industrial growth, governments often resorted to subsidies. However, over-reliance on subsidies can hinder long-term competitiveness. As the new energy industry matures and technological advancements occur, phasing out subsidies becomes necessary to encourage sustainable business development driven by technological innovation and market forces. Establishing robust market mechanisms is essential for the high-quality development of the new energy industry.

First, accelerating market-based electricity tariff reforms. Power sector reforms should be deepened to establish electricity tariff formation mechanisms that can accurately reflect changing supply-demand dynamics, resource scarcity, and environmental costs. Competitive market-based electricity tariffs will stimulate effective competition in power generation and distribution, unleashing market dynamism. Renewable energy-based power generation should be encouraged to participate in market competition, and policy instruments such as green certificate trading and electricity tariff subsidies should be implemented to promote clean energy development. Additionally, incorporating environmental costs into electricity tariffs through a carbon pricing mechanism can internalize carbon emissions costs and guide the green and low-carbon transition of both power generation and consumption.

Second, developing the green electric power transaction mechanism. New energy power companies should be empowered to directly sell green power at market-based tariffs to enhance their competitiveness. The green electric power certificate (green certificate) issuance and trading system should be refined, allowing green certificates to be used to facilitate the consumption of new energy-based electricity. The establishment of a new energy electric power quota system, requiring provincial jurisdictions to consume a specified amount of new energy electricity, can enable the turnover and compensation of environmental value through the carbon market. To increase market liquidity and risk management capabilities, the green electric power market should diversify its transaction products and methods. For instance, financial derivatives such as options and futures can be introduced.

Third, continuing to diversify transaction products and methods in the green electric power market. Introducing financial derivatives such as options and futures can enhance market liquidity and risk management capabilities. Strengthening the supervision and evaluation of new energy market entities is crucial to ensure fair, just, and transparent market practices. Cross-departmental policy coordination and communication should be reinforced to foster synergy and promote the development of the new energy industry.

5.4 Enhancing Resilience in New Energy Supply Chains

In the face of a complex and volatile international trade environment, the United States and other countries have imposed tariffs on renewable energy products and initiated countervailing investigations, aiming to contain China's burgeoning new energy industry. Under these circumstances, strengthening China's new energy industrial chains and enhancing the industry's resilience to risks becomes increasingly crucial.

First, optimizing industrial chain layout and enhancing independence and self-reliance. It is crucial to identify weak links in the new energy industrial chain, particularly in core components and critical materials. R&D investment should be increased to support corporate technological innovation and industrial upgrading, narrowing the gap with Western countries. Furthermore, upstream and downstream industrial chain enterprises should be encouraged to collaborate closely to form robust industrial ecosystems and enhance overall competitiveness. Prioritizing the development of a group of internationally competitive leading enterprises in critical mineral extraction and processing, as well as critical material and component manufacturing, is essential to increase industrial chain independence and self-reliance.

Second, expanding international cooperation for supply chain diversification. Enhancing international cooperation and exchanges is critical for reducing supply chain risks in the face of geopolitical uncertainty. It is essential to deepen capacity cooperation with Belt and Road Initiative (BRI) countries and other friendly nations, focusing on the new energy sector. By streamlining project approval processes and extending financial policy support, the government should encourage qualified new energy enterprises to participate in global market competition and expand their overseas footprint. Moreover, proactive efforts should be made to introduce advanced foreign technologies and management expertise to elevate China's international standing in the new energy industry.

Third, adjusting the import policy to encourage product imports. Considering the import dependency on specific components and raw materials, import policies should be adjusted by lowering tax rates and expanding the list of eligible source countries. Encouraging the import of more advanced and higher-quality products can help meet domestic market demand and improve product performance and

quality. Also, it provides opportunities for domestic enterprises to engage in technical exchanges and collaborations with advanced international companies, driving industrial upgrading and high-quality development.

Fourth, enhancing recycling technology for resilient supply chains. Recycling is a crucial strategy for improving resource efficiency and reducing environmental pollution. Increased R&D investment in critical technologies such as lithium-ion battery recycling is critical, as is assisting domestic enterprises in establishing a global waste battery recycling network. Recycling overseas waste battery resources can augment domestic raw material supply and reduce reliance on primary resources. By enhancing industrial resilience and sustainability, enterprises can focus on exporting high-value-added products to expand international markets and boost competitiveness.

In conclusion, a multifaceted approach is necessary to strengthen supply chains and enhance the resilience of the new energy industry. By optimizing industrial chain layout, expanding international cooperation, adjusting import policies, and promoting recycling, a more secure, stable, and efficient new energy industrial chain can be established. This will provide robust support for the sustainable development of China's new energy industry.

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