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The Development and Systematic Transfer of China's Green Energy Technology and Industry

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Abstract:
This study examines the development of China's green energy sector and its role in advancing international technology transfer, particularly toward developing countries facing acute energy shortages. Drawing on policy evolution, industrial expansion, and global comparative data, the paper illustrates how China has rapidly emerged as a global leader in renewable energy through large-scale investment, technological innovation, and the establishment of a comprehensive industrial chain. The study further analyzes China's successful cases of wind and solar technology transfer in Kazakhstan, Bosnia and Herzegovina, and Vietnam, demonstrating how these projects improve energy security, reduce carbon emissions, stimulate local employment, and support economic transformation. However, despite these advantages, China's international technology transfer efforts face persistent structural challenges, including geopolitical tensions, global protectionism, limited participation in international standard-setting, weaker global brand trust, and the developmental constraints of recipient countries. Overall, the paper argues that China possesses strong technological and industrial capacity for renewable energy diffusion, but its international influence is shaped not only by technical capabilities but also by political, institutional, and global governance factors.

Keywords: China, green energy, renewable energy industry, international technology transfer, Belt and Road Initiative

Introduction

Definition:

Green Energy: "Green energy" refers the energy type that aim to minimal the environmental impact during production and utilization. Green energy mainly includes solar, wind, hydro, biomass and geothermal power which are characterized by their renewable,

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environmentally friendly and low greenhouse gas emission traits. The advancement of green energy is a crucial alternative decision in the aspect of energy source which is made to confront global climate change and achieve sustainable development. In this passage, solar and wind energy will be primarily discussed. (CSEDS, Li Zhimin, 2024)

Clean Energy: "Clean energy" usually refers to energy sources that produce no climate-warming greenhouse gas emissions in their operation. Clean energy generally includes hydropower, solar, nuclear, and bioenergy energy. Compared with conventional fossil fuel, clean energy mitigates the emission of greenhouse gas and is crucial to the global decarbonization strategy. However, that doesn't mean they have zero impact on the environment. Although clean energy doesn't have emission during operation, they all have some "embedded emission." "There's no such thing as a true, perfect clean energy source," said by Jennifer Morris, a principal research scientist at MIT's Joint Program on the Science and Policy of Global Change and the MIT Energy Initiative. (MIT Climate Portal Writing Team, 2024)

International Technology Transfer: According to UNCTAD, International technology transfer (ITT) refers to the mechanisms for shifting information across borders and its effective diffusion into recipient economics. It encompasses numerous complex processes which range from innovation and international marketing of technology to its absorption and imitation. Included in these processes are technology, trade, and investment policies that can affect the terms of access to knowledge. Thus, policies make ITT complex and need carefully ponderation for each individual countries. (UNCTAD, Keith E. Maskus, 2004)

Global climate change is one of the most serious challenges that humans are confronting currently. Carbon dioxide (CO2) is the primary source of greenhouse gas in our atmosphere which contributes approximately 66% of the global warming effect. (WMO, 2020) Facing these kinds of challenges, the Paris Agreement set the foundation for international coordination. Currently, the European Union, Japan and the Republic of Korea, together with more than 110 other countries, have pledged carbon neutrality by 2050. (UN, 2020) Astoundingly, global primary energy production has grown by 60 percent since the beginning of the century. (Statista, 2025) Moreover, energy production, mainly the burning of fossil fuels, accounts for around three-quarters of global greenhouse gas emissions. (Our World in Data, Hannah Ritchie & Pablo Rosado, 2020) As a result, one of the most essential remedy to eliminate the process of global warming is to develop advanced innovative energy development which is the so called new-quality energy—green energy.

As the largest energy production and consumption nation around the world (Statista, 2025), China's transition toward green energy is based on the advocation of national environmental governance and global climate commitments. In September 2020, China also formally announced its goals of achieving peak carbon emission by 2030 and carbon neutrality by 2060. (CDSTM, 2021)

Looking back at history, the development of China's green energy has evolved from basic environmental principals published by governments to a comprehensive strategic framework constructed by industries. The 1995 Electricity Law established a legal foundation of green energy advance for the first time through requiring an environmentally friendly power construction, generation, supply system and encouraging the adoption, utilization and generation of renewable and clean energy. (Electricity Law of the People's Republic of China, 1995) As the need of energy restructuring intensified after the utilization of China, the 2005 Renewable Energy Law marked a marked a major step forward by creating a dedicated legal system which promote the development and utilization of renewable energy so as to protect the ecosystem and achieve the sustainable development. (Central People's Government of the People's Republic of China, 2005) Building on this foundation, the 2014 Energy Development Strategic Action Plan (2014-2020) elevated green energy to a national strategic priority, while also setting precise goals and policy measures to support the establishment of a large-scale renewable-energy development and construction of a cleaner energy system. It includes saving energy strategy, domestic energy strategy, green-energy strategy, and innovative technology strategy. (Central People's Government of the People's Republic of China, 2014)

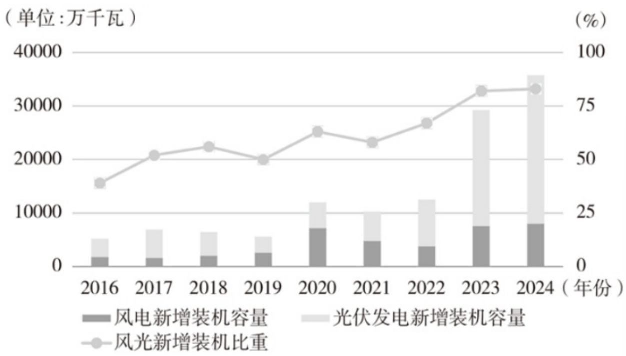

Figure 1 The installed capacity of green energy production in China (Institute for Carbon Neutrality, USTC)

Against the backdrop of favorable policy frameworks, China's green energy sector has undergone rapid expansion, and it's installed capacity has also experience a significant burgeon in recent years. Emerging and developing economies accounted for over 80% of global energy demand growth (IEA, 2025), the installed capacity of green energy surge to over 75% of the total installed capacity in the last decade as figure 1 demonstrates. (Institute for Carbon Neutrality, USTC, 2025) In 2024, China has just added 373 million kilowatts of renewable energy installed capacity which is 86% of all its newly installed power capacity. With the increase of installed capacity, in 2024, China's total renewable electricity generation has reached 3.46 trillion kilowatt hours, accounting for about 35% of the country's total power generation. (National Energy Administration (of China), 2025) Evidently, the industry about renewable energy has also developed in China. Until, July 31, 2024, there are more than 2million companies related to renewable energy in China. (Central People's Government of the People's Republic of China, 2024) Together, these trends delineate that China has established a continuously expanding green-energy ecosystem.

Compare with China, globally, clean energy technologies and infrastructure have taken over two third of the total investment in the aspect of energy. (IEA, 2024) In 2024, 80% of the total installed capacity in electricity was contributed by renewable energy and nuclear power, meanwhile, the renewable energy takes 32% of the total generation of energy. ((IEA, 2024) Clearly, globally, countries around the world are striving to deduce the carbon emission form the energy sector through developing and utilizing clean and renewable energy. While when contrast the development of renewable energy between China and the rest of the world, we can find that the development of renewable energy in China is much faster than that of the rest of the world. For instance, data from Ember delineated that China accounted for 55% of global solar generation growth, followed by the US (14%), the EU (12%), India (5.6%) and Brazil (3,2%). (Ember, 2025) Evidently, China has rapidly transformed into a global leader in the aspect of renewable energy in the resent decade.

On the other hand, owning a strong industrial foundation is shifting toward becoming a technology-driven nation. China has a substantial amount of investment in the clean energy sector, supporting scientific research, and benefiting from the low costs brought by well industrialization. Between 2015 and 2020, China's investment in the renewable energy sector consistently exceeded 100 billion US dollar each year. (Deloitte, 2020) As a result, in 2023, China's green and low-carbon invention patent application surged to 101,000 which is more than half of the world's total. (CHINADAILY, 2024) With the development of technology, the clean energy companies have also fostered in China. For instance, by 2015, 7 of the top 10 solar PV manufacturers were Chinese which includes Trina Solar, Yingli Green Energy, (Chinese-owned) Canadian Solar, Jingko Solar, JA Solar and Rene Solar. (Energy Policy, Eliakira Kisetu Nassary) Based on the development of renewable energy industries, the ability of produce green energy related products also has advantages over the world. For instance, in February 2025, the LCOE for onshore wind farms in China has dropped to an astonishing USD 30/MWh, which is only nearly half of the global average. (BNEF, 2025) Hence, based on the development of the entire industry chain, China has become one of the most competitive providers and innovators of renewable energy products globally.

Concentrating on developing countries which accounted for over 80% of global energy demand growth. BRI (Belt and Road Initiative) countries which are mostly constructed by developing countries have approximately 1.5 times energy intensity compared with global average which can be ascribed to their large population. (Huang et al., 2018). However, compared to other countries, BRI countries have lower energy efficiency, and the cost of the environment and resources is high. In particular, these countries consume approximately 50% of global primary energy but only account for about 30% of global GDP (Peng et al., 2022). Additionally, the 2,825 kilowatt-hours per capita electricity consumption is also well below the international average which is 3,295 kilowatt-hours per capita. (Deloitte, 2025) In essence, these reflect the predicament that developing countries represented by BRI countries have enormous energy shortage which can be ascribed to the large demand and inefficient use of energy. Despite the problem of energy shortage, the establishment of renewable energy system in developing countries is also disadvantaged with an approximately 341 watts of installed renewable-energy capacity per capita. (UNSTATS, 2025)

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Thus, with the inefficient use of renewable energy and the relatively low installed renewable-energy capacity per capita, Developing countries are needed to be associated so as to have more adequate, environmentally friendly and sustainable energy sources.
Confronting that condition, with a technological leadership, China is well-positioned to support these nations through International Technology Transition.
Successful Examples and Advantages
Successful Examples:
(1) Zhanatas Wind Power Project, Kazakhstan: Located in Sarysu District, Zhambyl Region, Kazakhstan, the Zhanatas Wind Power Project has an initial installed capacity of 100 MW. It consists of 40 wind turbines with a single unit capacity of 2.5 MW. It is a joint investment by State Power Investment Corporation (SPIC) China Power International and Kazakhstan's Visol Investment Company, with SPIC China Power entrusted with management. The project utilizes Chinese capital, technology, and international standards. It significantly improves the uneven power supply and demand situation in Kazakhstan, addressing the issue of a single power structure.
It meets the electricity needs of approximately 200,000 households. After full grid connection, it can output approximately 350 million kWh of clean energy annually, saving approximately 109,500 tons of standard coal and reducing carbon dioxide emissions by approximately 289,000 tons annually. On one hand, it addresses the local insufficient electricity supply, on the other hand, it can also reduce carbon emission, thus supporting environmentally friendly development.
(2) Ivovik Wind Power Project in Bosnia and Herzegovina: The Ivovik Wind Power Project, jointly invested and constructed by General Technology China National Technical Import & Export Corporation (GTC) and Power Construction Corporation of China (PCIC) Overseas Investment Co., Ltd. (PCIC Overseas Investment), has a total investment of approximately €133 million. It is the first energy project in Bosnia and Herzegovina invested and constructed under a foreign concession agreement. After grid connection, it is expected to generate approximately 260 million kWh of electricity annually, reducing carbon dioxide emissions by approximately 240,000 tons per year. The project utilizes advanced Chinese wind power equipment and technology. Domestically produced equipment accounts for over 90% of the entire project, and all equipment has obtained CE certification, and is also complying with EU and local standards.
It can be anticipated that the project is capable to improve the quality and stability of the local ecosystem and strongly promote the transformation and upgrading of Bosnia and Herzegovina's energy structure. Meanwhile, it also assists in establishing a more environmentally friendly energy supply system.
(3) Zhongshan Photovoltaic Power Plant, Vietnam: Taking advantage of the site's location at 11.2 degrees North latitude and its sloping orientation (higher in the south and lower in the north), the project innovatively adopted three technologies: rotating support structures, bifacial double-glass modules, and string inverters, to optimize power generation efficiency. After commissioning, the project can generate 67,400 MWh of clean electricity annually, reducing carbon dioxide emissions by approximately 53,000 tons per year, effectively addressing the power shortage in Khanh Hoa province.
Additionally, it also promotes revenue generation, enabling the local economy to thrive through green initiatives. After commissioning, the project generates approximately 13.86 billion VND (approximately 3,416 VND to 1 RMB) in annual tax revenue for the local government. Additionally, it also boosting the surrounding "tourism + photovoltaic" industry by approximately 20.79 billion VND in annual tax revenue. Moreover, it also assists employment conditions as at its peak construction period, it employed approximately 1,000 local workers; after commissioning, the localization rate of employees reached 96%.
In conclusion, international technological transformation in renewable energy technology brings mutual benefits to both technology-providing countries and technology-receiving countries. For technology-providing nations, it is capable of alleviating the problem of overcapacity. Moreover, it is also able to accumulate experience so as to enhance efficiency and minimize marginal effect. Additionally, given the characteristics of technology transfer, it can also eliminate outdated production and promote industrial upgrading. Similarly, For recipient countries, the introduction of renewable energy improves electricity supply reliability, reduces carbon emissions, stimulates local employment, and increases government revenue, while also enhancing long-term technical capacity and supporting sustainable economic transformation. Evidently, technology transformation of renewable and clean energy technology is a mutually beneficial mechanism for both technology-providing country and technology-receiving countries.
Advantages:
Evidence clearly demonstrates that China's renewable energy sector is currently experiencing an enormous and dangerous overcapacity. While, through international technology transformation, it is possible to resolve these problems. Data shows that China's own energy demand growth drop to below 3% in 2024 which is far lower compared with the historical averages of the energy demand

of the nation. (IEA, 2025) It highlights the weakness and risk that the domestic market isn't able to absorb soaring output. At the same time, global supply-chain projections delineates that seven of the twelve major manufacturers are going to each exceed 100 GW of module-production capacity by 2027, and total wafer and cell capacity among top firms is expected to reach 830 GW. Astonishingly, that is roughly twice of the global demand. (Energy Institute, 2025)Holding numerous of renewable energy industries, it is clear that China's production of clean energy product far exceeds its own demand. In order to address to this mismatch between production and domestic demand, China has increasingly relied on international technology transfer so as to absorb surplus capacity. Recording shows that in just the first half of 2024, 120,427 MW of solar modules have been exported. (Reuters, Gavin Maguire, 2024) Additionally, China has exported about $1.42 billion of turbines and components to the EU in 2024. (Reuters, Andrew Hayley, 2024) Thus, evidently, China's international technology transfer not only supports green development abroad but also acts as a crucial mechanism for resolving domestic overcapacity and stabilizing industrial operations.

Other than addressing domestic overcapacity, according to the research made by Zhejiang Gongshang University, international technology transformation is also able to strengthen the management of the technology market and increase its depth. Thus, assist in institutional development, and leverage the positive impact mechanism of the technology market's smoothness. (Zhejiang Gongshang University, Yu Liping, 2021) Meanwhile, the international transformation of renewable energy technology is also able to eliminate outdated production capacity and promote industrial upgrading as Lin Boqiang who is the head of the China Institute for Studies in Energy Policy at Xiamen University said, "The new regulations would help accelerate the elimination of outdated capacity and support the industry's long-term healthy development." (CHINADAILY, Liu Yukun, 2024) Thus, international technological transfer can bring immense benefit to technology-providing nation.

Current challenges and obstacles

Although China has rapidly ascent as an international producer and exporter of renewable energy technologies and has benefited the both itself and the technology-receiving country, there are still several structural weaknesses in China's capacity for effective international technology transfer. Such failures are not due to technological backwardness, but rather due to geopolitical mistrust, low rates of participation in global standard-making, low levels of brand endorsement, and constraints pertaining to the governance and development stages of recipient countries. Thus, these circumstances make for a complex environment in which China's technological advantages do not always transfer to a position of influence on the international stage.

One of the great weaknesses for China in technology transfer would be the continued geopolitical tensions that have affected how the world sees its supply chain for renewable energy. You can see this in the steps the U.S. took under the Uyghur Forced Labor Prevention Act (UFLPA). The U.S. Department of Homeland Security has been issuing another list of companies that are being blocked from entering the U.S. market and has been adding 37, including five major solar supply chain providers: Donghai JA Solar Technology, Hongyuan Green Energy, Jiangsu Meike Solar, Shuangliang Silicon Materials, and Xinjiang Energy Group. These companies are heavily tied to polysilicon production, and since Xinjiang previously supplied about half the global bulk of polysilicon, the UFLPA has a profound impact on perceptions of China's solar industry's legitimacy. That geopolitical scrutiny gives rise to a challenge to credibility. Although they have inexpensive and technologically advanced solar technology, the recipients of the technology may fear political backlash or sanctions for going too far with Chinese companies. (PV Magazine, Ran Kennedy, 2025) Therefore, China's ability to export or participate in the transfer programs of large technologies doesn't become restricted through technical measures but by political risks related with the adoption of Chinese technology.

Additionally, China's extremely competitive pricing has prompted European protectionist reactions. Low-cost Chinese solar panels helped facilitate the EU's energy transition but also forced European manufacturers to move their products to the periphery. A coalition of European companies filed a petition to the European Commission, accusing Chinese exporters of being in competition with them "unfairly". Despite the economic nature of the dispute, it has fed into the narrative that Chinese goods are "unfair" or "untrustworthy" which can be seen as aiding and abetting broader pushback against Chinese technological penetration. (Yu Chen, 2015) That means geopolitical pressure and international skepticism constitute a strong structural weakness that China cannot simply overcome by upgrading its technology.

Moreover, China's is lack of the ability of shaping the global standard. Even as China leads worldwide solar generation, its industry relies on the kind of industrial standards developed decades ago by the West. For instance, ASTM International (previously the American Society for Testing and Materials) has established global standards related to the performance, testing techniques and safety of solar panels for decades. (America Board for Codes

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and Standards, 2015) These standards are utilized and have global market access. In the meantime, modern-day solar cell technologies are in the United States, and they originated in Western research institutions. In 1954, Bell Laboratories developed the first practical solar cell with silicon, and the early advantage of technology leadership led to a path-dependent advantage in standard definition, certification systems, and industrial norms. (APS, 2009) This historical supremacy has led many international institutions and certification bodies to still utilize Western benchmarks to this day. And even if Chinese technologies are cutting-edge, they are frequently assessed based on standards that are put together without Chinese involvement. This undermines China's bargaining power and restricts its capacity to set new rules in global markets. Since developing countries often rely on international certification to certify imported technologies, China's less role in rulemaking means their technology transfer efforts might appear to be less aligned with international best practices. Thus, making their products less attractive.

Another concern is about China's brand and reputation abroad. While technology from Chinese firms is inexpensive, not everyone will think of it as a product they trust. Chinese renewable energy products were skeptical in many countries over their long-term reliability, durability and after-sales support. China's renewable energy sector is still relatively young compared with well-established Western companies and the establishment of global brand influence requires both time and transparency, as well as regular results. In addition, Chinese overseas development financing typically leaves recipient countries to do their own due diligence. From the Chatham House research, Chinese development financing is "recipient led". (Lee Jones, NA)This approach also means Chinese lenders and contractors fail to properly evaluate project risks and longevity of investments. Consequently, recipient governments need to prove the projects' financial independence, negotiate fairly, and guarantee development benefits to the local community. For countries with poor administrative capacity, this model adds to the uncertainty and makes Chinese projects less attractive. Poor brand trust is also associated with geopolitical considerations, thereby increasing skepticism over whether Chinese technology is the safest or most sustainable option. Collectively, these effects cast doubt on China's prospects to present itself as a viable, long-term partner in technology transfer programs. Considerations in the Development Stages of recipient countries.

However, China's weaknesses in technology transfer are compounded by challenges inside recipient countries themselves too. For many developing countries, especially in Africa, energy shortages go on — Sub-Saharan Africa has almost 600 million people without access to electricity. Many big-picture programs, including one called Mission 300, look to send electricity to 300 million people by 2030. (World Bank Group, 2019) However, this kind of ambitious goal requires substantial domestic reforms, stabilizing governance, and sound infrastructure planning at the domestic scale. These conditions are frequently absent. But according to Rostow's stages of economic growth, many developing countries are still in earlier stages of economic development, characterized by low levels of industrialization and weak institutions and by reliance on external financing. Such structural vacuums prevent them from absorbing high-tech solutions such as renewable energy systems. So, while China may be open to the transfer of technologies, the recipient states may also find it difficult to harness technology. Also, because Chinese development financing mandates that recipients manage project planning and risk, countries that have inadequate technical capacity are unlikely to be well positioned to fulfill these expectations. (Spur ECONOMICS, Viren Rehal, 2024) This raises the possibility of delays, overruns, or local resistance etc., which will obstacle the process of international technological transformation.

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