



The Impact of Chinese Investment on Pakistan's Infrastructure in the Renewable Energy Sector

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Article Info

P-ISSN: 3051-3340

E-ISSN: 3051-3359

Impact Factor (RSIF): 8.34

Volume: 07

Issue: 02

Received: 18-04-2026

Accepted: 20-05-2026

Published: 22-06-2026

Page No: 01-06

Abstract

Making the shift to renewable energy is a pressing concern for developing nations aiming to alleviate energy poverty, climate change, and sustainable economic growth. In Pakistan, a nation grappling with persistent energy shortages and dependence on imported fossil fuels, foreign investment has become a growing solution to address infrastructure challenges and gaps. In this context, one of China's flagship projects under the Belt and Road Initiative (BRI), China–Pakistan Economic Corridor (CPEC), has become a key initiative for infrastructure development in Pakistan. This paper explores the impact of Chinese investment on Pakistan's renewable energy sector, covering various aspects such as the development, integration, and sustainability of renewable energy infrastructure projects.

It is a mixed-methods approach, focusing on quantitative analyses of energy capacity trends and investment costs from 2014 to 2024, and qualitative policy analysis and case studies of the major renewable energy projects like Quaid-e-Azam Solar Park, and Jhimpir Wind Corridor. This analytical framework is based on theory related to Foreign Direct Investment (FDI), Energy Transition Theory, and Sustainable Development Theory. The results show that Chinese infrastructure investment has been an important enabling factor for the development of renewable energy in Pakistan, especially in strengthening the transmission grid, transport infrastructure, and integration with the grid. Some of the study's insights are the key challenges of financial pressures in the power sector, governance and transparency issues, institutional fragmentation and environmental and land use risks. Recommendations are made to increase the sustainability and developmental benefits of these investments in the long term.

DOI: <https://doi.org/10.54660/IJFTIBU.2026.7.2.01-06>

Keywords: China–Pakistan Economic Corridor (CPEC), Renewable Energy Development, Infrastructure Investment, Energy Transition, Foreign Direct Investment, Pakistan

1. Introduction

The transition to renewable energy has gained momentum, resulting in an increased demand for infrastructure to catalyze sustainable energy systems, especially in developing regions and economies. Reliable energy transition depends on the establishment of a strong infrastructure such as transmission networks, transportation systems and institutional frameworks to integrate renewable energy into national power systems and ensure long-term energy security. Foreign investment has come to be a major tool to overcome infrastructure constraints and support energy transition.

Pakistan is plagued with enduring energy issues such as energy supply shortages, reliance on fossil fuels for energy needs and escalating environmental pressures. China-Pakistan Economic Corridor (CPEC) is one of the flagship projects of China's Belt and Road Initiative (BRI), and a major foreign infrastructure investment program in the country. Chinese investment in Pakistan's energy generation, transportation, and transmission systems has reshaped the country's infrastructure, paving the way for new

opportunities in renewable energy exploration within the massive projects. The massive projects in energy generation, transportation, and transmission infrastructure have transformed the infrastructure landscape in Pakistan and created new opportunities for renewable energy exploration. This paper explores the impact of Chinese investment on the progress of renewable energy in Pakistan and its sustainability. The research thoroughly investigates how foreign infrastructure investment affects energy transition in a developing economy by analyzing the trend of infrastructure development, policy changes, and the outcomes of individual projects.

1.1. Background: Pakistan's Energy Crisis

The Pakistan energy system has been plagued by structural imbalances, high dependence on import of energy supplies and weak transmission and distribution facilities. These ongoing challenges have hindered economic stability, discouraged foreign investment and hindered sustainable development. The nation has vast possibilities in solar, wind, hydropower, but capital shortage, technology limitations, etc. have prevented the country from tapping these resources. With the launch of CPEC in 2015, the energy sector in Pakistan has been impacted both directly and indirectly in terms of investment in infrastructure. Early works on CPEC were mainly around conventional power generation, but later projects placed more emphasis on sustainable development, modernization of the grid, and the integration of renewable energy, which aligns with the Renewable Energy Policy (2019) of the Government of Pakistan.

1.2. Research Significance

This study contributes to the existing literature since most of it has either studied the geopolitical aspects of CPEC or has been based on positive studies on individual energy projects without considering the infrastructural ecosystem that enables the integration of renewable energy. The study brings conclusions and recommendations based on evidence for Pakistan's energy planning, for the Chinese institutions that are implementing the Green Belt and Road Initiative, and for international development organizations that are interested in sustainable energy transitions in developing countries.

2. Literature Review

The contribution of FDI and infrastructure for renewable energy development is reviewed. FDI and infrastructure development for renewable energy is reviewed.

Foreign Direct Investment (FDI) is regarded as one of the most important sectors to boost economic growth, especially in capital-intensive industries such as energy and infrastructure. However, in the field of renewable energy, FDI can mobilise financial resources, transfer technology and establish the infrastructure necessary for domestic markets to establish in most developing countries that cannot do so on their own (Sadorsky, 2013) [24]. Studies have shown that foreign investment plays a crucial role in facilitating renewable energy transition in emerging markets, especially in the absence of developed domestic capital markets (Doytch & Narayan, 2016) [9].

Renewable energy systems, in particular, are highly infrastructural, needing transport corridors, substations, transmission networks and balancing systems in the grid to operate properly. Research has revealed that without proper infrastructure, transaction costs, curtailment risk, and

scalability issues are still high (Bhattacharya *et al.*, 2016) [4]. A positive relationship between renewable energy consumption and FDI in infrastructure-intensive industries has been found to be statistically and significantly positive in developing countries (Doytch & Narayan, 2016) [9]. Another route of technology transfer is FDI—an increase in energy sector FDI is correlated with more rapid adoption of renewable technologies in the presence of regulatory stability (Shahbaz *et al.*, 2018) [25].

2.1. Energy Transition and Sustainable Infrastructure

Energy transition is the process of shifting the energy system to a low-carbon, renewable energy system on a systemic basis over a long time. This "transformation" is not only technological but also requires systemic change in economic systems, governance systems, social policies and physical infrastructure (Sovacool, 2016) [26]. Sustainable infrastructure is a key variable in energy transition – particularly in developing economies – and poses fundamental questions of quality and availability. Supportive physical infrastructure is essential for the maximum benefits of renewable energy technologies.

Empirical studies reveal that the ability of infrastructure influences the uptake of renewable energy. An archaic grid will require more curtailment of intermittent renewables and suffer from reliability concerns, while flexible, modern grids will offer better resiliency and performance for intermittent renewables (Bhattacharya *et al.*, 2016) [4]. Additionally, investment in infrastructure also demonstrates a longterm energy transition commitment and attracts further domestic and foreign investment (Aklin *et al.*, 2016) [2].

2.2. The Chinese Investment in Pakistan's Renewable Energy Sector

It has been observed that Chinese investment in renewable energy has become one of the biggest factors influencing the country's energy development. The projects comprise Quaid-e-Azam Solar Park in Bahawalpur, one of the biggest solar projects in South Asia, and several wind farms in the Gharo–Jhimpir corridor financed by the Chinese. The main sources of Chinese funding are policy banks at preferential or semi-concessional terms, such as the Export-Import Bank of China and China Development Bank, frequently under the guise of public-private partnerships with a sovereign guarantee (Huang & Chen, 2020) [14].

In addition to investments in direct generation, Chinese infrastructure projects such as the Matiari–Lahore ±660 kV HVDC transmission line have significantly boosted Pakistan's electricity generation capabilities. EPC contracts and joint ventures have facilitated technology transfer, and the transfer of technology has included the application of standard construction methods, upgraded PV modules and high-voltage transmission systems, although localization of domestic production is still relatively low (Zhou *et al.*, 2018) [34].

2.3. Theoretical Framework

This study is based on three theories. This study is based on the Foreign Direct Investment (FDI)-led Growth Theory (Borensztein *et al.*, 1998) [5], which describes the process of FDI's facilitating capital accumulation, productivity and the introduction of technology to the host country. According to infrastructure-led Development Theory (Calderón & Servén, 2010) [6], infrastructure (roads, electricity networks, transport

networks) is a necessary condition for sectoral development. Energy Transition Theory (ETT) (Sovacool, 2016; Köhler *et al.*, 2019) [26, 19] focuses on the systemic transformation from fossil fuel-based energy systems to low-carbon energy systems, emphasising the importance of infrastructure as a characteristic of energy transitions and the risk of carbon lock-in.

The Dependency Theory (Frank, 1967; Cardoso & Faletto, 1979) [10, 7] serves as a useful framework to consider the potential for "upgrading" in Pakistan via Chinese investment and whether such investment is likely to lead to "structural dependence". Sustainable Development Theory (WCED, 1987; UNDP, 2021) [33, 27] gives a normative framework to determine whether infrastructure investment is serving the long-term environmental and social sustainability goals.

3. Research Methodology

This research is a mixed methods research design and uses a quantitative and qualitative method. The explanatory sequential design both quantitatively analyzes secondary data to find trends and relationships between infrastructure investment and the growth of renewable energy capacity and qualitatively investigates to explain and give meaning to the empirical results.

The quantitative data is derived from NEPRA State of Industry Reports (2014-2024), AEDB renewable projects database, IRENA renewable capacity statistics, World Bank development indicators and reports by the CPEC Authority. Some of these key indicators are installed renewable energy capacity (solar, wind, hydropower), transmission infrastructure investment, employment multipliers, and CO₂ emission factors.

Qualitative data comprises semi-structured interviews with

the policymakers, regulatory authorities, the energy developers, and technical experts; case studies of the Quaid-e-Azam Solar Park and Jhimpir Wind Corridor; and policy document analysis of policies such as the Alternative and Renewable Energy Policy 2019. The study spans a long period of time—from 2014 to 2024—to capture short- and long-term patterns of infrastructure development and renewable energy results.

4. Findings and Discussion

4.1. China Pakistan Economic Corridor (CPEC) Infrastructure investments

The experiences from Chinese investment under CPEC have proven to be transformative in addressing Pakistan's longstanding needs in the areas of energy, transportation, and transmission networks. From 2015 to the early 2020s, Chinese financed infrastructure in Pakistan was the highest compared to other bilateral and multilateral sources of funding (CPEC Authority, 2023) [8]. Investment was incremental, beginning with addressing short-term energy shortfalls through the quick installation of generation capacity, followed by transmission and logistics infrastructure projects that now enable the integration of renewable energy.

The ±660 kV Matiari-Lahore HVDC line is one of the projects constructed by State Grid Corporation of China (SGCC) that significantly improved Pakistan's ability to deliver power from the generation-heavy southern provinces to the demand-heavy northern provinces with minimal losses. Transportation infrastructure developments, such as the building of highways and motorways, lessened transport constraints to accessing remote areas of high renewable resource potential in Balochistan and the interior Sindh.

Table 1: Major CPEC Infrastructure Projects Relevant to Energy Transition.

Project Category	Key Projects	Strategic Significance
Energy Generation	Quaid-e-Azam Solar Park, Jhimpir Wind Projects	Expansion of renewable energy capacity
Transport	Karakoram Highway (Phase II), ML-1 Rail Upgrade	Improved logistics and regional connectivity
Transmission	Matiari-Lahore HVDC Line (±660 kV)	Enhanced grid integration and reduced transmission losses
Digital	Fiber-optic networks, broadband expansion	Real-time grid monitoring and coordination

Source: Compiled from NEPRA (2022) and CPEC Authority (2023)

4.2. New technologies and innovations

The renewable energy capacity in Pakistan has increased significantly in the last 15 years, solar power and wind power have seen the highest growth rates over these 15 years,

especially after the introduction of upgrades in transmission and transport connectivity. Table 2 shows the quantitative trend for non-hydroelectric renewable capacity between 2014 and 2024.

Table 2: Non-Hydro Renewable Installed Capacity in Pakistan (2014–2024, MW)

Year	Solar (MW)	Wind (MW)	Other Non-Hydro (MW)	Total Non-Hydro (MW)
2014	178	106	0	284
2015	400	255	0	655
2016	650	308	10	968
2017	1,030	1,035	25	2,090
2018	1,300	1,235	30	2,565
2019	1,500	1,335	35	2,870
2020	1,600	1,435	40	3,075
2021	1,750	1,535	45	3,330
2022	1,900	1,735	55	3,690
2023	2,100	1,985	70	4,155
2024	2,400	2,200	95	4,695

Source: NEPRA State of Industry Reports 2014–2024; AEDB Renewable Project Database; IRENA Renewable Capacity Statistics (2014–2024)

The data show a significant jump in non-hydro renewable capacity post 2016-2017, which can be attributed to CPEC transmission upgrades and regulatory changes by NEPRA/AEDB. The growth rates of solar and wind have been well over 100% and 200% respectively over the period 2014-24, with infrastructure investment proving effective in catalysing project feasibility in resource-rich regions.

4.3. The provision of technology transfer and capacity building

The diffusion of technology and institutional learning due to Chinese infrastructure investment has been observed in the renewable energy industry. Standardized construction methods, cutting-edge PV modules, wind turbines suitable for low wind speed, and high-voltage transmission systems were introduced by Chinese companies. In the infrastructure-related areas, the implementation of infrastructure management technologies, forecasting tools and system optimization practices were most successful, as Pakistani utilities have engaged with Chinese companies in the transfer process. Technical capacity was strengthened in the transmission system operation and maintenance and on-the-job knowledge transfers and training programs were undertaken.

The level of technology uptake was, however, different across projects. Domestic manufacturing of renewable energy equipment remained limited, though there was significant improvement in operational skills, thus leaving

Pakistan reliant on imported technology, and vulnerable to risks of the foreign supply chain. This reinforces the importance of complementary industrial policies to achieve maximum long-term benefits.

4.4. Case Studies

With the help of China, the Quaid-e-Azam Solar Park in Bahawalpur (1,000 MW) proved the feasibility of utility scale solar generation in Pakistan. The project was able to be quickly built and connected to the national grid with improved road access and the development of project management and grid synchronisation.

The Jhimpir Wind Corridor in Sindh (totaling some 1,200 MW installed in several farms) grew quickly after specific investments in infrastructure. There were several wind projects supervised by Chinese companies; improving access to transport and upgrading transmission lines lowered logistical constraints and enabled quicker, cheaper development. Wind project bundling resulted in economies of scale and efficiency gains in operations.

4.5. Social, Economic, and Environmental Impacts.

These effects include social, economic and environmental. The development of renewable energy projects under CPEC has created measurable employment benefits at different stages of CPEC. Table 3 shows the estimated number of jobs created by renewable energy projects between 2014 and 2024.

Table 3: Estimated Employment Generated by Renewable Energy Projects (2014–2024)

Year	Direct Jobs	Indirect Jobs	Total Jobs
2014	4,500	3,200	7,700
2016	9,600	7,100	16,700
2018	17,800	13,600	31,400
2020	21,500	16,700	38,200
2022	25,800	20,600	46,400
2024	32,500	26,800	59,300

Source: AEDB project employment multipliers; IRENA employment factors; NEPRA project reports

Renewable energy capacity growth has also contributed to greenhouse gas emission reductions by displacing fossil fuel-

based electricity generation. Table 4 presents estimated CO₂ emissions avoided through renewable generation.

Table 4: Estimated CO₂ Emissions Avoided through Renewable Energy Generation (2014–2024)

Year	Renewable Generation (GWh)	CO ₂ Avoided (Million Tons)
2014	1,050	0.6
2016	2,950	1.7
2018	6,150	3.6
2020	8,100	4.7
2022	10,900	6.4
2024	14,800	8.7

Source: Author's estimates based on NEPRA generation data and IPCC emission factors (IPCC, 2019; NEPRA, 2024)

The continuous growth of avoided emissions is a result of the compounded effect of renewable energy development supported by Chinese infrastructure investments. There was a net increase in emissions in Pakistan as energy demand has increased with renewable energy expansion but the increase has been slowed down, which helps in meeting Pakistan's Paris Agreement commitment.

The main institutional framework for renewable energy investments with CPEC has been the public-private partnership (PPP). In Pakistan, independent Chinese power producers entered into LPPAs and government guarantees

with state institutions, as well as joint ventures. In 2024, the number of PPP-based renewable projects increased to 37 projects (3,450 MW), with improved infrastructure and regulatory frameworks leading to growing investor confidence (AEDB, 2023; CPEC Authority, 2023) [3, 8].

4.6. Challenges and Risks

Although significant progress has been made, the study highlights a number of key challenges that limit the long-term sustainability of infrastructure-based renewable energy development. Financial sustainability is the most pressing

issue: Systemic fiscal pressures of circular debt accumulation and long-term capacity payments set under power purchase agreements (PPA) on the power sector of Pakistan puts fiscal constraints on investment capacity in renewable sources in the future (NEPRA, 2023) ^[21].

A second challenge is governance and transparency issues. Project implementation under the CPEC has been centralized, which has lowered the accountability, especially when it comes to contract negotiations. Coordination failures, regulatory delays, and policy inconsistencies, due to a fragmented institutional system where planning, regulatory, and project approval responsibility lies with a range of federal and provincial agencies with overlapping mandates, have led to policy inconsistencies and delays (Wolf, 2019) ^[31].

The third sort of challenge is associated with environmental and land-use risks. Solar and wind installations are quite large and may compete for space in areas with productive farmland or critical environmental values. There has been a concern from the local communities regarding noise pollution, ecosystem disruption, and unequal benefits distribution around projects such as Jhimpir. Environmental and social impact assessments are not regularly carried out or enforced (Gallagher & Qi, 2020) ^[11].

In addition, there is a lack of flexibility in the grid and energy storage, which limits renewables. Even after installing transmission infrastructure, intermittency of solar and wind generation shows there are still grid constraints on the side of absorption. If the grid is not modernized, forecasting is not developed, and energy storage is not addressed, a technical limit to the integration of renewables will be reached in the future (Geels *et al.*, 2017) ^[13].

5. Policy Recommendations

This study makes 6 major policy recommendations based on its findings for improving long-term sustainability and development impact of Chinese investment in Pakistan's renewable energy sector.

In the first place, Pakistan needs to further strengthen the link between infrastructure development and renewable energy. Investment decisions need to be made in the context of overall energy-infrastructure planning approaches that directly connect to renewable energy objectives, while renewable resource mapping, demand forecasting, and transmission expansion planning need to be linked to transport investments.

Second, there is a need of financial sustainability reforms now. Recommendations for policy makers are to move slowly toward competitive bidding systems, incentives with a time limit, and market-driven renewable energy pricing. The innovative instruments of green finance, such as green bonds and blended finance, need to be created for decreasing reliance on sovereign guarantees and foreign financing.

Third, the Explicit localization criteria should be embedded in EPC contracts and joint ventures in order to further promote technology transfer. Industrial policies, tax incentives and skills development initiatives should be targeted at the local production of renewable energy components, minimising import requirements and maximising value addition within the country.

Fourth, governance and transparency systems need to be improved. Enhanced reporting standards, independent project audits, parliamentary scrutiny and independent project review for major infrastructure projects would improve accountability and trust of the public. Better

information about financing arrangements and risk-sharing is needed for a better-informed policy debate.

Fifth, better embedding of environmental and social safeguards in the infrastructure and renewable energy development process. More stringent environmental and social impact assessments procedures must be required and enforced, especially for projects in ecological sensitive areas. It is important to build engagement into the project life cycle and mitigate land use issues to achieve equitable distribution of benefits.

Sixth, Pakistan should diversify its strategy of international cooperation and include Chinese investment in it. Pakistan's dependence risks would be minimised, competitive pressure on financing terms would strengthen and overall negotiating position of Pakistan would improve if it engaged with multilateral development banks and private investors in energy development partnerships.

6. Conclusion

This study has proved that CPEC has played an important role as an enabling factor for the development of Pakistan's renewable energy sector to a considerable extent but under certain conditions. Infrastructure development, especially in transmission networks, transport connectivity, and grid integration, has opened up significantly more opportunities for the deployment of solar and wind power, allowing for a growth from a total of 284 MW in 2014 to around 4,695 MW by 2024.

The results validate the key tenets of Energy Transition Theory: infrastructure is not a supportive but a constitutive element of renewable energy transitions, especially in cases of physical and institutional constraints. Technology diffusion, job creation and emissions reductions are also resulting of Chinese investment, although localization is uneven and the effects of socio-economic benefits are limited.

Meanwhile, concerns about Dependency Theory, such as pressure on finances from externally funded capacity, little domestic industry production, and transparency issues with government administration highlight the fact that foreign financing of infrastructure alone is not enough. The transition to sustainable renewable energy needs coherent national governance structures, robust regulatory systems, long-term energy planning and intentional measures to build the capacity of institutions.

The findings of this study are not limited to Pakistan. The Pakistani experience provides important insights into the enabling effects and structural risks of foreign infrastructure investments in developing economies in Africa, South Asia, and Southeast Asia generally in their infrastructure transitions to renewable energy. The key take-away message is that investment in infrastructure sets the stage for a transition to renewable energy but is not a panacea to the institutional and policy frameworks necessary to guarantee sustainable development.

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How to Cite This Article

Usman N, Zhu Z. The impact of Chinese investment on Pakistan's infrastructure in the renewable energy sector. *International Journal of Foreign Trade and International Business Upgradation*. 2026;7(2):1-6.
doi:10.54660/IJFTIBU.2026.7.2.01-06.

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