

Renewable Energy Transition in Pakistan: Policy Challenges and Opportunities

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ABSTRACT

Pakistan is confronted with acute energy challenges, such as persistent shortages, significant dependency on hydrocarbon imports and increasing environmental concerns. This article looks at Pakistan's move toward renewable energy, providing an analysis of policy frameworks as well as implementation barriers and opportunities for sustainable development. By analyzing the policies of the government, its international collaborations and developments in the sector, this study identifies the major constraints such as lack of a grid, lack of financing, lack of regulations and lack of capacity to handle the institutions. But there are also opportunities, as the country possess vast solar and wind resources, international climate finance, technological developments and increasing interest from the private sector. The paper suggests that policy coherence, favorable regulatory frameworks, grid infrastructure, and public-private collaboration be strengthened in the country to expedite Pakistan's journey toward sustainable energy systems which are consistent with SDG 7.

Keywords: Renewable energy, Pakistan, Energy transition, Sustainable development, Policy analysis, SDG 7

Introduction

The Pakistani energy sector is at risk across a variety of fronts, Inhibiting economic progress and long-term economic sustainability. The country has over 230 million people with fast-growing urban sprawl and with an increasing energy requirement way over the available supply (Government of Pakistan, 2023). The country suffers from a high reliance on imported fossil fuels (primarily oil and gas), which makes it economically vulnerable and is a major source of climate-warming gases. Pakistan imports about 85 percent of its oil needs and substantial quantities of natural gas,

leading to balance-of-payments pressures and energy security anxieties (State Bank of Pakistan, 2022).

The renewable energy shift is thus a challenge and an opportunity for Pakistan, to answer to its energy security, the sustainability of its environment and to the wealth of its economy, all in one set of actions. This transition is consistent with Sustainable Development Goal 7 (SDG 7) on ensuring universal access to affordable, reliable, and sustainable energy by 2030 (United Nations, 2015). This imperative is recognized in Pakistan's pledge to reduce the carbon intensity of its electricity production by 30% by 2030, (to limit the use of fossil fuels) made under the Nationally Determined NDC in 2015 (Climate Change Division, 2021).

Pakistan has rich renewable resources, for example, solar radiation of 5-7 kWh/m²/day, wind coastlines of the average speed of >7 m/s (Alternative Energy Development Board, 2020). Research suggests of a potential of more than 60,000 MW power potential of wind and over 2,900,000 MW of solar power (World Bank, 2018). The real deployment, however, is still at such a state of deployment that it is limited compared to this potential, and renewable energy accounted for only 11% of installed capacity in 2023.

This paper focuses on transition in renewable energy in Pakistan and includes an extensive investigation of policy, implementation issues and potential for development. The study provides insight into how developing countries cope with intricate and overlapping energy transitions, which must also address development concerns and climate obligations.

Table 1: Pakistan's Energy Mix and Renewable Energy Potential

Energy Source	Current Installed Capacity (MW)	Percentage of Total	Estimated Potential (MW)	Utilization Rate (%)
Natural Gas	12,300	30.0%	-	-
Hydroelectric	9,971	24.3%	60,000	16.6%
Coal	5,200	12.7%	-	-
Furnace Oil	4,800	11.7%	-	-
Nuclear	3,530	8.6%	-	-
Wind	1,335	3.3%	346,000	0.4%
Solar	600	1.5%	2,900,000	0.02%
Bagasse/Biomass	200	0.5%	1,800	11.1%
Total	41,000	100%	3,307,800	1.2%

Source: National Electric Power Regulatory Authority (2023); Alternative Energy Development Board (2020)

Literature Review and Global Context

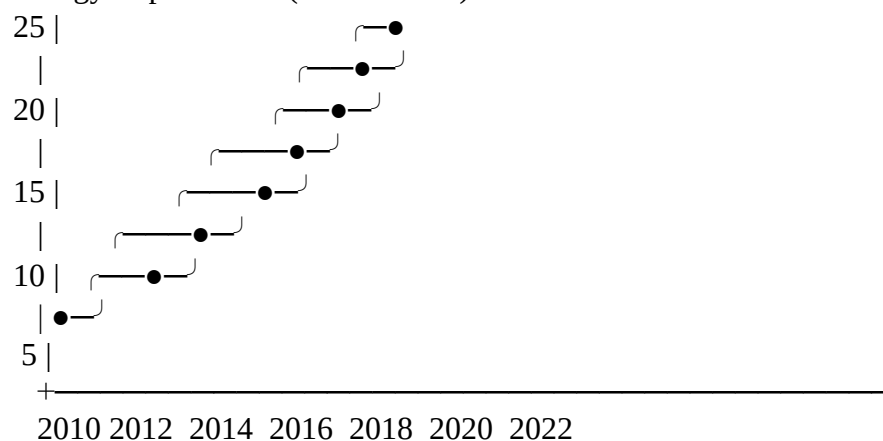
Across the world, the transition towards renewable energy has begun to advance at a rapid pace, spurred on by technological advancements, falling costs, and climate imperatives (IRENA, 2023). Transitions of developing countries are complex

processes that are constrained due to lack of finance, institutional capacity and other pressing development priorities (Bazilian et al., 2021). Yet they also have advantages in the ready availability of renewable resources, and squeezed potential for “leapfrogging” traditional energy infrastructure.

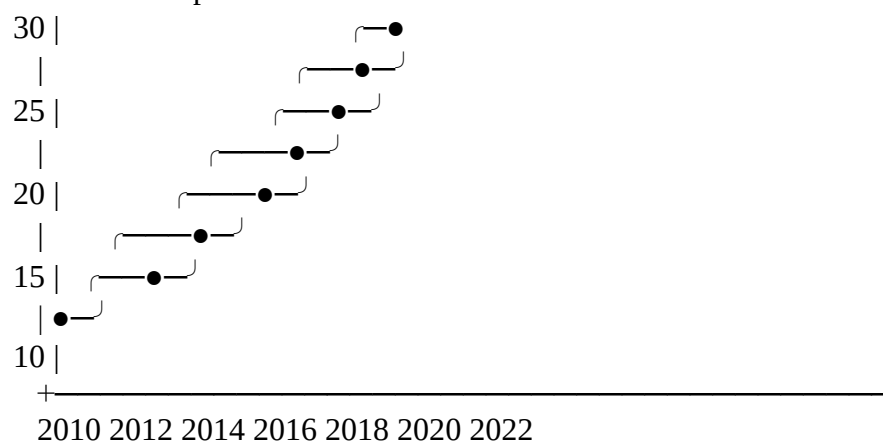
Pakistan’s power sector is dominated by chronic shortages, inefficiencies, and a large capacity based on fossil fuels (Kessides, 2013). Load shedding is still an ongoing problem causing industrial productivity and quality of life to decline. The power sector further grapples with a chronic conundrum envisaged in the circular debt, touching PKR 2.5 trillion (Power Division, 2023). Pakistan has formulated a number of renewable energy policies, such as the Alternative and Renewable Energy Policy 2019, and provincial level programs (Ministry of Energy, 2019). Notwithstanding, it is not immune to the barriers of regulatory complexity, financing limitation and institutional coordination. Global relationships, especially with China under China-Pakistan Economic Corridor (CPEC), changed landscapes of energy (Hussain et al., 2021). The CPEC plan has projects for renewable energy with an investment of over \$3 billion, reflecting a rising international interest to the energy transition in Pakistan.

Figure 1: Pakistan's Energy Import Dependency (2010-2023)

Energy Import Costs (Billion USD)



% of Total Import Bill



Source: State Bank of Pakistan (2022)

Methodology

This paper adopts a mixed-methods analysis of quantitative analysis of data for the energy sector and qualitative review of texts related to policy and stakeholder views. Data sources consist of government policies and plans, statistical reports, academic studies, industry reports and an article on the status of global and Chinese waste treatment industry. The analytical model is used to investigate the four dimensions of transition to renewable energy: political environment, technological development, economy and institutions. The quantitative dataset includes energy production and installed renewable energy capacity, economic metrics and drivers from 2010-2023, and the qualitative analysis areas include policy content analysis and comparative analysis of institutions.

Current State and Policy Framework

By 2023, the country's total installed electricity generation capacity stood at (about) 41,000 MW, of which renewable energy sources accounted for (roughly) 4,500 MW or 11% of the total (National Electric Power Regulatory Authority, 2023). This is well below the government's goal of 30% renewable energy by 2030. Recent additions include large projects like the Quaid-e-Azam Solar Park with 1,000MW capacity, wind farms in Sindh province with a total capacity of over 1,000MW, and distributed solar programs allowing rooftop installations.

The renewable energy policy regime in Pakistan has evolved through various stages. The Alternative and Renewable Energy Policy 2019 aims for a renewable energy share of 30% by 2030 and maps out a technology diversification framework, the role of the private sector, and institutional strengthening (Ministry of Energy, 2019). It includes elements such as competitive procurement for utility-scale, net metering for distributed generation, technology-specific priorities, and simplified interconnection processes. The National Electricity Policy 2021 contains the overall guidelines on the electricity sector emphasizing on least cost generation planning and modernization of the grid.

Provinces have established supporting policies, also in recognition of their constitutional role in energy planning. The solar and wind-power initiatives reflect federal-provincial harmony in Punjab's Solar power Policy 2015, in Sindh Wind Power Policy, in Khyber Pakhtunkhwa renewable energy strategy in which importance has been attached to micro-hydel projects, and in Baluchistan solar and wind-power development programs respectively.

The NEPRA is the key regulator, and it regulates the tariffs' structure, the technical standards, and the market which are set by the feed-in-tariff rules, as well as the competitive bidding rules, grid codes and net metering regulations. The investment in private sector has furthermore increased significantly due to competitive bidding, resulting in significant reduction of the solar and wind power tariff to less than 3 cents/kWh from nearly 14 cents/kWh since 2015 (Central Power Purchasing Agency, 2022).

Table 2: Major Renewable Energy Projects in Pakistan (2020-2023)

Project Name	Type	Capacity (MW)	Location	Developer	Status	Investment (\$ Million)
Quaid-e-Azam Solar Park	Solar	1,000	Punjab	TBEA/Zonergy	Operational	1,500
Jhimpir Wind Farm	Wind	300	Sindh	Zorlu Energy	Operational	450
Gharo Wind Corridor	Wind	950	Sindh	Various	Operational	1,400
Tarbela 4th Extension	Hydel	1,410	KPK	WAPDA	Operational	823
Karot Hydropower	Hydel	720	Punjab	Three Gorges	Under Construction	1,700
Thar Coal Mine Solar	Solar	300	Sindh	SSRL	Planned	200
Azad Pattan Hydel	Hydel	700	AJK	CPGC	Under Construction	1,500
Total	Mixed	5,380	Various	Various	Various	7,573

Source: Central Power Purchasing Agency (2022); Various project developers

Key Challenges

Pakistan's renewable energy shift confronts serious barriers on different fronts. The most limiting factor is grid infrastructure, as the existing transmission network needs to be significantly expanded to open up space for on- and off-grid renewable generation, especially in the developing world where there are huge potential renewable resources in remote areas without grid connectivity (National Transmission and Dispatch Company, 2022). The EVR restriction means that renewable energy production cannot exceed a generation-injection based on current transmission limits. Variable renewable energies pose grid balancing challenges that need additional forecasting, flexibility measures and storage solutions, none of which are currently available to Pakistan's grid operator.

Financial and economic obstacles are substantial barriers as well. Renewable energy projects are capital-intensive with the proposed investments far higher than what domestic financial resources can provide; and that restricted access to such low-cost long-term financing has been a deterrent to the development of these projects, notwithstanding the reduction in technology costs (State Bank of Pakistan, 2022). Here, forex fluctuations and delayed payments from distribution companies pose financial risks, pushing up the project costs and denting investor interest. These

challenges are further worsened by the circular debt crisis which stands over PKR 2.5 trillion in power sector dues.

Regulatory and policy disconnects derail investor certainty and project bankability. Governance in the energy sector is complex and scattered in the federal and provincial divide on the other hand their parallelism prevails among the state and federal governments on this account (Planning Commission, 2022). Capricious policy adjustments and after-the-fact changes to incentive regimes do not offer the regulatory certainty needed for investment on a sustained flow basis.

Sector growth is constrained with technical and human limitations as local technical capacity on project development, grid integration, and operation and maintenance are insufficient. Educational institutes and curriculum have failed to keep up with industry (Higher Education Commission, 2021). Dependency on foreign equipment and parts inflates the cost of projects while a lack of domestic manufacturing capacity constrains economic benefits and technology transfer.

A universe of vertically integrated, state-owned enterprises does not foster competitive pressures and efficiency gains in the power industry. Partial market reforms to open up competition and private participation have resulted in underperformance of the sector as well as renewable energy penetration.

Table 3: Financial Analysis of Renewable Energy Barriers

Challenge Category	Estimated Cost Impact	Timeline Impact	Risk Level	Mitigation Priority
Grid Infrastructure	\$5-8 billion investment needed	5-7 years delay	High	Critical
Circular Debt	15-20% cost increase	2-3 years delay	Very High	Critical
Currency Risk	10-15% cost volatility	Ongoing	High	High
Regulatory Uncertainty	20-25% risk premium	1-2 years delay	High	High
Technical Capacity	5-10% cost increase	2-4 years delay	Medium	Medium
Land Acquisition	5-15% cost increase	1-3 years delay	Medium	Medium
Equipment Import	8-12% cost increase	6-12 months delay	Medium	Low

Source: Industry estimates and expert consultations (2023)

Opportunities and Potential

Despite significant challenges, Pakistan possesses exceptional opportunities for renewable energy development. The country's geographic location and climate provide world-class renewable energy resources with high solar irradiation levels across most regions, particularly in Balochistan and southern Punjab, offering opportunities for utility-scale and distributed solar development. Daily average solar irradiation ranges from 4.5-7.0 kWh/m², among the highest globally (Pakistan

Meteorological Department, 2022). Coastal areas in Sindh and Balochistan possess exceptional wind resources with capacity factors exceeding 35%, while the Gharo-Keti Bandar wind corridor alone has potential for over 50,000 MW of wind power generation.

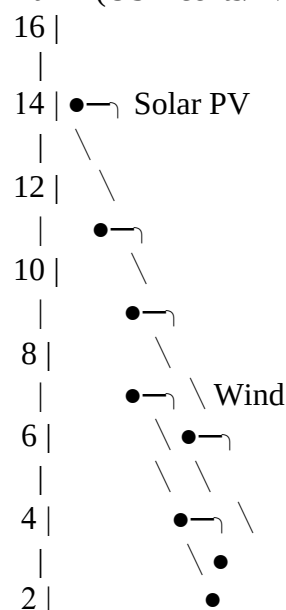
Northern regions contain substantial unexploited hydroelectric resources estimated at over 60,000 MW, with small and medium-scale hydel projects offering opportunities for rural electrification and local economic development (Water and Power Development Authority, 2023). Global renewable energy technology costs have declined dramatically, making renewable energy cost-competitive with fossil fuel alternatives in Pakistan, with solar photovoltaic costs decreasing by over 80% since 2010 and wind power costs falling by 60%.

Pakistan's vulnerability to climate change and commitment to NDCs creates opportunities for accessing international climate finance through mechanisms such as the Green Climate Fund, Asian Development Bank, and World Bank climate facilities (Climate Investment Funds, 2022). Strategic partnerships with countries like China, Germany, and Japan provide technology transfer, financing, and capacity building opportunities. Growing private sector interest, both domestic and international, creates opportunities for accelerated deployment, with successful auction programs attracting competitive bids from leading global developers.

Economic benefits include substantial import substitution potential, with renewable energy development reducing dependence on costly fuel imports and improving energy security and balance of payments. Each MW of renewable energy capacity can save thousands of dollars annually in fuel import costs (Ministry of Finance, 2023). Renewable energy projects create employment opportunities in manufacturing, construction, operation, and maintenance, while local content requirements can enhance technology transfer and industrial development.

Figure 2: Renewable Energy Cost Trends in Pakistan (2015-2023)

Tariff (USD cents/kWh)



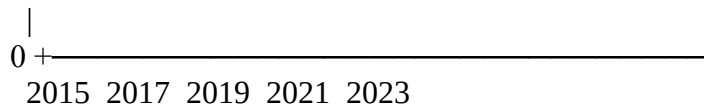
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Legend: ● Solar PV ● Wind Power

Source: Central Power Purchasing Agency (2022)

It brings environmental and social dividends, including reduced local air pollution and local greenhouse gas emissions, while also enhancing Pakistan's climate-related efforts. Urban populations with high pollution exposure are also beneficiaries of the health benefits due to enhanced air quality (Pakistan Environmental Protection Agency, 2022). Renewable decentralized technologies also have the flexibility to provide electricity in remote areas and to stimulate economic development in rural areas, including productive uses of energy in agriculture, small business and social services.

Rapid development of digital technologies such as smart grids, tech energy storage and demand response systems offer provisions for updating energy infrastructure in Pakistan to the extent that it can handle high shares of renewable energy penetration (Digital Pakistan Initiative, 2021). By bringing AI, IoT sensors and blockchains together, the renewable energy production, distribution and consumption could be much more efficient.

Case Studies and International Comparisons

The Quaid-e-Azam Solar Park in Bahawalpur is Pakistan's showcase renewable energy project that indicates both success and difficulties in up-scale implementation. Staged development was completed from 2015 to 2017 and the park reached a 1,000 MW capacity via international partnership with Chinese companies under The China Pakistani Economic Corridor (CPEC) framework and used competitive procurement and standardised documentation to ensure cost-effectiveness. The project successfully showcased the potential of Pakistan for setting up a world-class renewable energy infrastructure and supplying clean electricity to the tune of over 500,000 households, though the land related complexities, grid interconnections and payment delays hampered the financial viability.

The wind corridor development in the province of Sindh is a case of successful engagement of the private sector and competitive market development. Since 2012, over 1,300 MW of wind farms that will be tendered have been commissioned, with various international investors and technology suppliers participating in competitive tenders that successively delivered forever lower tariffs while preserving the bankability of the projects. On the other hand, wind power development is focused primarily in remote areas and has revealed grid integration issues in terms of transmission limitations and system balancing needs, calling for the need to develop the grid and forecasting systems.

Pakistan net metering policy promotes distributed solar generation and serve as case for regulation and market agility. Since its launch in 2015, the program has evolved through several iterations to respond to technical, economic and policy hurdles, with more than a total of 150 MW in capacity installed across residential, commercial and industrial customers. The program has lowered participating customers' electricity

bills while providing system value in terms of distributed generation, but scaling will require attention to capacity constraints on the grid and rate design.

Pakistan has much to learn from foreign experiences of renewable energy. In India, the achievements through high ambition, focused renewable energy agencies, financial innovation such as the use of green bonds and viability gap funding and local manufacturing paired with local content requirements gain traction for large-scale deployment (Ministry of New and Renewable Energy, India, 2022). Key lessons to inform comprehensive energy transition planning are offered by Morocco's system-oriented approach, which connects renewable energy, employment goals and economic development, proactive grid expansion, strategic international partnerships, and regional market integration.

The Implementing Agencies in Bangladesh A harmonization of both public sector implementing entities, and private sector implementing partners (Infrastructure Development Company Limited, 2022) through the following sub-programs have chalked up path breaking learnings for rural electrification through market based approaches with private sector delivery, household solar systems through microfinance inclusivity, capable line agencies and scaling potential of replicable standard technologies across national riding on rapid up scaling.

Table 4: International Renewable Energy Comparison

Country	RE Target (%)	Current RE Share (%)	Key Success Factors	Lessons for Pakistan
India	50% by 2030	38% (2023)	Dedicated institutions, ambitious targets, financial innovation	Institutional framework, manufacturing development
Morocco	52% by 2030	37% (2023)	Integrated planning, international partnerships	Strategic partnerships, grid modernization
Bangladesh	40% by 2041	4% (2023)	Distributed approach, microfinance integration	Rural electrification, financing innovation
Turkey	30% by 2023	44% (2023)	Competitive markets, regulatory stability	Market reforms, predictable regulations
Vietnam	20% by 2030	27% (2023)	FIT policies, private sector engagement	Tariff mechanisms, investment attraction
Pakistan	30% by 2030	11% (2023)	Resource potential, cost competitiveness	Need accelerated implementation

Source: IRENA Global Energy Transformation Report (2023)

Economic and Social Impact Analysis

Development of renewable sources of energy leads to substantial direct economic benefits in the form of the savings in foreign exchange on fuel imports and in terms of

employment and industrial development. It is estimated that reaching 30% renewable energy by 2030 would save over \$2 billion in fuel import costs each year and generate more than 200,000 jobs direct and indirect (Pakistan Institute of Development Economics, 2022). Decline in energy imports positively impacts balance of payments and exchange rate stability, while low cost of electricity promotes industrial competitiveness and minimizes economic risk associated with international fuel price fluctuations.

Decentralized renewable energy technologies can broaden electricity access in remote areas and help with rural economic development through productive uses of in agriculture and small enterprises and social services (Rural Support Programs Network, 2023). Environmental playing: Curbing local air pollution and thereby greenhouse gas emissions that help Pakistan fulfil its climate commitments, the nudge towards cleaner air could directly benefit the health of the population, especially urban residents in high pollution areas.

But distributional effects need to be considered when designing renewable energy policies for an equitable development. There could be regional discrepancies as energy-rich provinces gain more from the development of renewable energy, and it also threatens low-income consumers as the higher electricity tariffs are likely to affect them. Grid connected renewables are likely to have greater benefits in urban areas, whereas in rural areas there is a greater need for targeted programs for policy-inducing inclusive development.

Policy Recommendations

Achieving successful transition to renewable energy sources can only occur through a holistic approach to policy making and substantial changes to institutions, financial mechanisms, technical support and energy markets. Specifically, it is also time to establish an independent federal renewable energy authority that has the independence and resources to co-ordinate policy delivery, facilitate approvals, and provide technical know-how. Enhancing federal-provincial coordination through formal structures for the alignment of policies, best practices and regulatory measures across jurisdictions will serve to strengthen implementation.

Development of the financial sector, including the creation of a dedicated green investment bank, which can provide long-term, concessional finance for renewable energy projects, and leverage international climate finance and private sector finance to deliver additional support. It is important to resolve circular debt by implementing wide-ranging power sector reforms, such as tariff rationalization, targeted subsidy use and governance improvements for timely payment to renewable project development companies and for investor confidence.

Modernization of the grid system will depend on advancing the development of transmission infrastructure to link renewable resources to demand centers, and to bolster system flexibility and reliability. So, investments in smart grid technologies such as smart meters, demand response, and energy storage will allow the system to more efficiently use variable renewable generation and make headline debacles like Friday less likely.

Success of such initiatives will lead to trafficking knowledgeable workforce to the renewable energy industries, both in the country as well as abroad. Setting up research

centers and innovation hubs for renewable energy will help to develop local solutions and to tailor them to our conditions in Pakistan and will help in nurturing indigenous innovation.

Table 5: Policy Implementation Roadmap (2024-2030)

Phase	Timeline	Key Actions	Expected Outcomes	Investment Needed (\$ Billion)
Phase 1	2024-2025	- Establish RE Authority - Grid code updates - Competitive auctions	2,000 MW additional capacity	2.5
Phase 2	2025-2027	- Grid infrastructure - Manufacturing incentives - Skills development	5,000 MW additional capacity	6.0
Phase 3	2027-2030	- Market integration - Storage deployment - Regional trade	10,000 MW additional capacity	12.0
Total	2024-2030	Comprehensive transformation	17,000 MW (30% target)	20.5

Source: Author's analysis based on government targets and industry estimates

Future Outlook and Scenarios

In the baseline scenario assuming the continuation of the existing policies and progress trend, the renewable energy capacity is expected to be 15,000-20,000 MW by 2030 and therefore account for 20-25% of the total installed capacity, which is below the target of 30%. If the policy implementation were to be improved and an enhanced plan would be put in place, an accelerated track facilitates addressing the constraints and proposed reforms, which in principle could achieve 25,000 -30,000 MW alone of renewable capacity by 2030, at least meeting, if not surpassing, the 30% freely target.

An ambitious reform, as well as strong international backing and game-changing technologies, would allow Pakistan to reach 40,000 MW+ of renewables capacity by 2030, making the country the dominant regional renewable energy player with the highest economic and ecological benefits. Such a scenario would necessitate prolonged political will, systemic institutional change and never before seen international collaboration.

The fundamental sources of uncertainty shaping the trajectory of renewable energy development in Pakistan are policy continuity (which, in turn, critically depends on political stability and consistent policy implementation), macroeconomic conditions that determine access to international finance, technological development which impacts renewable energy production costs and performance, regional energy trade opportunities, and climate-induced effects on energy infrastructure that mandate an adaptive management stance.

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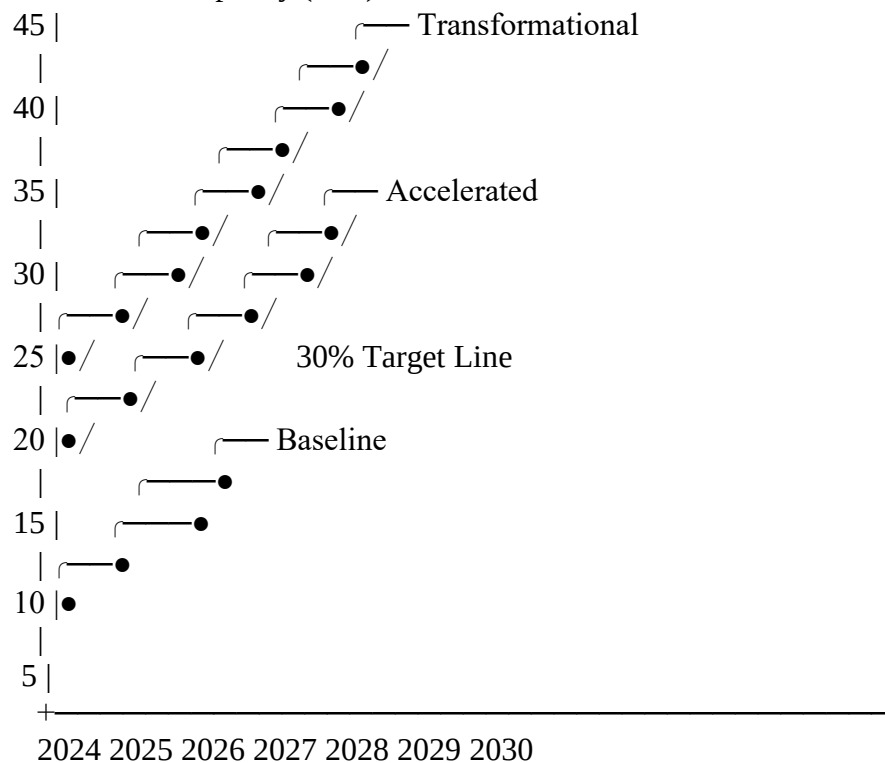
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Figure 3: Pakistan Renewable Energy Scenarios (2024-2030)

Installed RE Capacity (GW)



Current: 4.5 GW (11%)

Source: Author's projections based on policy analysis

Conclusion

Pakistan's solar led energy transition is not only necessary but is imperative: an opportunity for sustainable development. There Is a compelling business case for scaling- up renewables in Argentina, which has abundant renewable resources, rapidly falling technology costs, and an emerging interest from the private sector to invest in the country. Nevertheless, there are substantial barriers such as grid infrastructure limitations, financing restrictions, regulatory unevenness and institutional weakness that has to be taken forward in an organized way for capitalizing this potential.

Success hinges on a wide-ranging policy reform effort, including institutional strengthening in new dedicated renewable energy institutions, financial sector development that includes new green investment vehicles, adoption of smart technologies for a more modern grid, and an investment in capacity building through education and training. Global collaboration and climate finance present further possibilities to expedite advances, optimizing development co-benefits of technology transfer, knowledge sharing and financial assistance.

The renewable energy revolution is more than replacing what feds want with new sources -- it is changing where Pakistan's development goes, away from failure, insecurity, and poverty and toward the sustainable and secure. Drawing from international experiences, but tailoring solutions to meet local conditions, will be key

to success and will necessitate long-term political commitment, coordination among stakeholders, and adaptive management to address the myriad of issues and fully exploit the potential of Pakistan's renewable energy resources.

Pakistan's moderate approach to renewable energy reflects broader global trends, accommodates unique local realities and development needs. The timing is opportune with rich funding, dropping technology costs, and widespread acknowledgement, however decisive action is needed to move from potential to practice. Unlocking this potential will require an unprecedented convergence of action across all levels of government, continuing private-sector involvement and the application of new financing instruments to overcome longstanding barriers and drive transformational change.

The move towards clean, renewable energy reflects Pakistan's commitment to sustainable development, climate change and energy security for the existing and future generations. With right policies supported by sufficient funds and strong implementation, Pakistan can reach its renewable energy goals in support of global climate targets and a sustainable energy future that includes economic development, social well-being, and environmental protection.

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