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PAKISTAN'S PIONEERING WIND POWER PROJECT - FFC ENERGY LTD

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The **"Annual State of Renewable Energy Report Pakistan 2024"** has been developed under the **"Clean Energy Transition Programme Pakistan"** by the S**ustainable Development Policy Institute (SDPI),** Islamabad. The authors of the report include **Mr. Sarim Zia** (Researcher at SDPI), **Engr. Ubaid ur Rehman Zia** (Head of Energy Unit at SDPI), **Engr. Ahad Nazir** (Head of Centre for Private Sector Engagement at SDPI), and **Dr. Khalid Waleed** (Research Fellow at SDPI).

The report highlights SDPI's unwavering commitment to advancing Pakistan's clean energy transition through research-driven insights, strategic policy analysis, and actionable recommendations. It reflects the collective expertise and efforts of the authors, ensuring that it serves as a comprehensive resource for policymakers, stakeholders, and development partners working to accelerate renewable energy adoption in Pakistan. The peer review of this report was conducted by Ms. Sarah Siddiq (Senior Editor, Centre for Aerospace and Security Studies). The authors extend their gratitude for her invaluable feedback and expert input, which helped refine the quality and direction of this work. The team acknowledges and extends special gratitude to Muhammad Umer (Research Associate, SDPI) for his valuable support and contributions during the development of this report. His assistance has been instrumental in ensuring the quality and robustness of the document.

The "Annual State of Renewable Energy Report Pakistan 2024" derives its debate and analysis from extensive stakeholder consultations and policy evaluations conducted under SDPI's Network for Clean Energy Transition (NCET). The report incorporates critical frameworks, including the Integrated Generation Capacity Expansion Plan (IGCEP) 2024–2034, the Transmission System Expansion Plan (TSEP) 2024–2034, and the National Electricity Plan (2023–2027). These strategic plans aim to modernize Pakistan's grid infrastructure, enhance energy efficiency, and expand the share of renewable energy within the country's overall energy mix.

The report examines emerging solutions and opportunities in renewable energy financing, such as green sukuks, blended finance models, and international mechanisms like the Green Climate Fund (GCF). Technological innovations, including Power-to-X (P2X) technologies, advanced grid systems such as SCADA, and smart grids, are also highlighted as key enablers for integrating variable renewable energy sources. Additionally, the findings emphasize the importance of localized renewable energy solutions, spotlighting initiatives like Punjab's solar expansion programs, Sindh's wind corridor development, and Khyber Pakhtunkhwa's focus on hydropower. These insights collectively provide actionable pathways to address challenges and accelerate Pakistan's transition towards a sustainable energy future. Furthermore, the authors acknowledge the convening role of key organizations whose collaboration and support have been instrumental in shaping the "Annual State of Renewable Energy Report Pakistan 2024." These organizations include:

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Umair Hassan

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Abbreviations and Acronyms

ADB	Asian Development Bank
ARE	Alternative Renewable Energy
BESS	Battery Energy Storage Systems
Btu	British Thermal Unit
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CC	Combined Cycle
CCI	Council of Common Interests
COD	Commercial Operation Date
CPEC	China-Pakistan Economic Corridor
CTBCM	Competitive Trading Bilateral Contract Market
DER	Distributed Energy Resources
DISCO	Distribution Company
ESG	Environmental, Social, and Governance
EV	Electric Vehicle
EIA	Environmental Impact Assessment
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWh	Gigawatt-hour
HDIP	Hydrocarbon Development Institute of Pakistan
HPP	Hydropower Project
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IGCEP	Integrated Generation Capacity Expansion Plan
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IT	Information Technology
KE	K-Electric
kWh	Kilowatt-hour
MoCC	Ministry of Climate Change
MoE	Ministry of Energy
MoF	Ministry of Finance
MTOE	Million Tonnes of Oil Equivalent
MW	Megawatt
MWh	Megawatt-hour
NCCP	National Climate Change Policy

NDC	Nationally Determined Contributions
NEECA	National Energy Efficiency and Conservation Authority
NEPRA	National Electric Power Regulatory Authority
NTDC	National Transmission and Dispatch Company
P2G	Power-to-Gas
P2H	Power-to-Heat
P2X	Power-to-X
P2P	Peer-to-Peer (Energy Trading)
PKR	Pakistani Rupee
PPP	Public-Private Partnership
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Sources
ROW	Right-of-Way
RLNG	Regasified Liquefied Natural Gas
SAARC	South Asian Association for Regional Cooperation
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SECP	Securities and Exchange Commission of Pakistan
SLM	Smart Load Management
TCEP	Transmission Capacity Expansion Plan
TSEP	Transmission System Expansion Plan
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
VRE	Variable Renewable Energy

Executive Summary

This "Annual State of Renewable Energy Report - Pakistan 2024" comes at a critical juncture for the country. Amidst escalating climate change impacts and ongoing economic challenges, Pakistan's transition to renewable energy (RE) offers a vital pathway toward sustainability, resilience, and energy security. As detailed in this year's analysis, harnessing renewable sources can alleviate Pakistan's energy supply issues, reduce environmental degradation, and support economic growth—ultimately ensuring an accessible, affordable, clean, and secure energy future.

Over the past decade, Pakistan's RE sector has grown steadily, though it still constitutes a relatively small fraction of the energy mix. As of 2024, renewables account for 6.8% of total power generation capacity, primarily through wind, solar, and hydropower. This steady expansion aligns with government objectives to reduce reliance on imported fossil fuels and shift toward cleaner, domestically sourced energy.

To guide these efforts, key policy frameworks—including the National Electricity Plan, the Indicative Generation Capacity Expansion Plan (IGCEP) 2024–2034, and the Fast Track Solar PV Initiatives—are steering the country toward a 30% RE share by 2030. These measures focus on competitive bidding, localized manufacturing, and cost reductions to foster a stable RE market. According to the IGCEP, total capacity should reach 57,000 MW by 2034, with renewables potentially making up to 57% of the mix. Within this trajectory, Pakistan's RE capacity is expected to rise to 13,860 MW by 2034, driven by accelerated solar and wind development, as well as innovative applications like agrivoltaics that enhance both energy supply and food security.

This year's report adopted a multi-pronged methodology (see Annex I for details) and integrated data-driven assessments of the current energy mix and infrastructure, policy and regulatory evaluations of key instruments like IGCEP 2024–2034 and the National Electricity Plan 2023–27, as well as examinations of emerging trends and focused case studies—such as the uptake of Solar PV. By combining national and international data sources, reviewing sectoral and infrastructural dynamics, and exploring the role of sector coupling ("P2X") and carbon markets, this approach provides a holistic roadmap. It identifies current gaps, offers actionable insights, and aligns with global best practices, guiding stakeholders toward a more resilient and sustainable energy future. The result is a comprehensive analysis of Pakistan's clean energy transition, focusing on four key areas **(see Annex II for the Key Guiding Questions)** essential to understanding and advancing RE development.

Pakistan's RE expansion faces several critical barriers, including infrastructural constraints, regulatory complexities, and financing gaps. These challenges are compounded by outdated grid infrastructure, voltage stability issues, and limited transmission capacity. The report emphasizes the need for targeted grid modernization, harmonized federal-provincial policies, and innovative financing instruments like green sukuks to overcome these obstacles. Tariff adjustments, such as NEPRA's wind energy tariff at approximately PKR 4.28 per kWh, demonstrate steps toward enhanced cost competitiveness. Financing remains a significant hurdle, as financial institutions perceive renewable energy investments as high-risk and demand high collateral. Introducing concessional financing options and credit guarantees can bridge this gap and encourage greater investment.

Emerging technologies and trends, including Power-to-X (P2X), offer transformative potential by integrating renewable electricity into heating, transport, and industrial processes. Technologies such as Power-to-Gas (P2G) and Power-to-Heat (P2H) enhance grid flexibility, reduce fossil fuel reliance, and enable robust energy storage. The report also explores carbon markets as financing mechanisms that align with Pakistan's commitments under the Paris Agreement while attracting international investment in RE projects.

An examination of solar PV adoption reveals how recent initiatives—such as the 2022 Fast Track Solar PV Initiatives—leverage competitive bidding and transparency to accelerate solar deployment. Rooftop and utility-scale installations, supported by clear policy signals and improved regulatory frameworks, reduce dependence on costly imported fuels, enhance energy security, and support Pakistan's long-term sustainability.

Underpinning these focus areas is the urgent need for substantial investment. Pakistan's clean energy transition requires an estimated USD 72 billion by 2034, covering generation capacity expansion, grid modernization, and renewable integration. Specifically, USD 62–64 billion is needed to meet a projected 50% increase in electricity demand, with another USD 8.7 billion earmarked for upgrading and expanding transmission networks. In alignment with its Nationally Determined Contributions (NDCs), Pakistan aims to achieve a 60% RE share by 2030—an effort that will require approximately USD 101 billion in total, including USD 20 billion dedicated solely to scaling renewable capacity by an additional 12 GW.

Renewables play an integral role in fulfilling Pakistan's climate strategy. Solar, wind, and hydropower are pivotal in reducing greenhouse gas emissions, enhancing resilience, and enabling sectors like textiles, manufacturing, and agriculture to operate with near-zero emissions. Renewable technologies also sustainably power energy-intensive processes—such as air conditioning, desalination, and irrigation—thus positioning Pakistan favorably in the global green industrial landscape.

The Transmission System Expansion Plan (TSEP) 2024-34 addresses grid-related bottlenecks to ensure seamless RE integration. Meanwhile, IGCEP 2024-2034 and the National Electricity Plan 2023-27 call for distributed renewable solutions and grid modernization to improve energy access and security. The report underscores that mobilizing climate finance is paramount, highlighting international funding frameworks like the Green Climate Fund (GCF) and the World Bank's adaptation financing. Instruments such as green sukuks, impact bonds, and blended finance models diversify funding sources while meeting Environmental, Social, and Governance (ESG) standards. Equitable financial mechanisms, along with distributed RE solutions, will ensure that remote and underserved communities gain affordable, clean power **(see Annex III Policies and Initiatives Guiding Pakistan's Path to Energy Sustainability).**

Pakistan's commitment to expanding its RE capacity is evident in ambitious targets and **Provincial-Level Initiatives.** Each region is capitalizing on its natural resources to advance national goals of reducing fossil fuel reliance and promoting sustainable development.

Punjab: As an industrial hub, Punjab drives large-scale solar projects like the Quaid-e-Azam Solar Power Project (1,000 MW), representing about 40% of Pakistan's installed RE capacity. The province also promotes off-grid solutions, including small PV plants, run-of-river hydropower, and biofuel projects. Punjab aims to increase domestic solar production to 1,500 MW, reinforcing its leadership in the RE landscape (Punjab Board of Investment & Trade, 2024).

Sindh: Rich in wind and solar resources, Sindh hosts the Gharo-Keti Bandar wind corridor, attracting numerous Independent Power Producers (IPPs). Wind farms and solar projects—both grid-connected and off-grid—electrify remote areas and public buildings. The province also explores waste-to-energy options, diversifying its renewable portfolio (Sindh Energy Department, 2024).

Khyber Pakhtunkhwa (KP): Capitalizing on abundant water resources and mountainous terrain, KP prioritizes hydropower development. Various projects, ranging from small to large-scale, will collectively add over 2,200 MW to the national grid, leveraging KP's natural advantages (Pakhtunkhwa Energy Development Organization, 2024).

There is no doubt that Pakistan's RE sector is on the cusp of significant transformation, yet it faces a range of **Challenges and Opportunities.** These factors span policy frameworks, financing mechanisms, infrastructure development, and regional integration—all critical to advancing Pakistan's clean energy transition. Despite progressive policies such as the Alternative Renewable Energy (ARE) Policy, 2019, the National Electricity Plan 2023-27, and the IGCEP 2024-2034, regulatory and institutional hurdles persist. Discrepancies between federal and provincial regulations often lead to inconsistent enforcement and delayed project approvals. **Establishing a single-window clearance system for permits could streamline procedures, reduce bureaucracy, and build a transparent regulatory environment that encourages investor confidence and accelerates project deployment.**

This report highlights the sector's reliance on imported components, such as solar panels and wind turbine parts, which exposes Pakistan to global price volatility, customs duties, and currency fluctuations. Developing local manufacturing capabilities through Public-Private Partnerships (PPPs) and tax incentives would lower expenses, reduce import dependency, and create jobs across the renewable supply chain, aligning with Pakistan's long-term objective of achieving energy independence. Financing remains a significant challenge, as financial institutions tend to view renewable energy investments—particularly for smaller developers—as high-risk and demand high collateral. This report emphasizes that introducing concessional financing options, structured finance products, and credit guarantee mechanisms, facilitated by entities like InfraZamin and the Pakistan Credit Guarantee Company, can bridge this gap. Concurrently, green sukuks offer a promising avenue to attract Middle Eastern investors, diversifying Pakistan's funding sources for renewable projects.

Outdated grid infrastructure further hampers the integration of intermittent renewable sources such as solar and wind. Voltage stability issues, limited transmission capacity, and frequent curtailments hinder efficient energy distribution, especially in high-potential regions like Sindh and Balochistan. This report underscores the need for significant investments in smart grids, advanced metering, and high-voltage transmission lines to improve grid stability, unlock renewable potential, and reduce financial losses associated with underutilized assets. Bureaucratic barriers, including complexities in securing land rights and Right-of-Way (ROW), prolong development timelines and increase costs. The absence of consistent legal frameworks for land acquisition and clear guidelines for distributed energy resources (DERs) limits the expansion of decentralized generation. Standardized land acquisition procedures, incentives for DER integration, and streamlined ROW protocols are identified as crucial steps to enhance project feasibility.

This report also finds that many projects encounter delays and cost overruns due to outdated or insufficient technical feasibility assessments. Comprehensive and timely grid-integration studies, along with enhanced technical capabilities, are essential to improve the accuracy of project planning, reduce risks, and boost developer and financier confidence. Furthermore, the national grid often faces overloading and instability, particularly in semi-urban and rural areas, preventing renewables from being fully utilized despite their "must-run" status. Policy and regulatory uncertainties, ranging from the transition to competitive bidding and bilateral trading to the absence of frameworks for emerging technologies like battery storage and hydrogen, dampen investor confidence. Enhanced regulatory support, intergovernmental coordination, and clear guidelines for advanced technologies are necessary to encourage private-sector participation and innovation, as highlighted by this report.

Yet, these challenges also highlight the sector's immense **Growth Potential**. By adopting sector coupling technologies, such as Power-to-X (P2X), Pakistan can integrate RE into heating, transportation, and industrial processes. Converting surplus renewable power into gas (P2G) or heat (P2H) enhances grid flexibility, reduces fossil fuel dependence, and improves energy storage. These strategies can position Pakistan as a leader in innovative renewable applications in South Asia.

Local manufacturing capabilities offer another strategic opportunity. Establishing special economic zones dedicated to renewable technology production would attract international technology transfers, develop local expertise, create jobs, and reduce dependency on imports. This approach would strengthen Pakistan's competitiveness in the global renewable supply chain and foster long-term sustainability.

Investments in advanced grid management systems—like **SCADA** and other smart grid technologies—would improve operational efficiency, facilitate the integration of variable renewables, and maintain grid stability. Pilot projects demonstrating these technologies can attract investment and guide effective modernization approaches. Learning from regional examples, such as India's rooftop solar initiatives or Bangladesh's battery storage solutions, can inform Pakistan's policy design and encourage regional cooperation on cross-border energy trade. Harmonized policies, competitive bidding frameworks, fiscal incentives, and capacity-building programs can accelerate renewable adoption efficiently and sustainably.

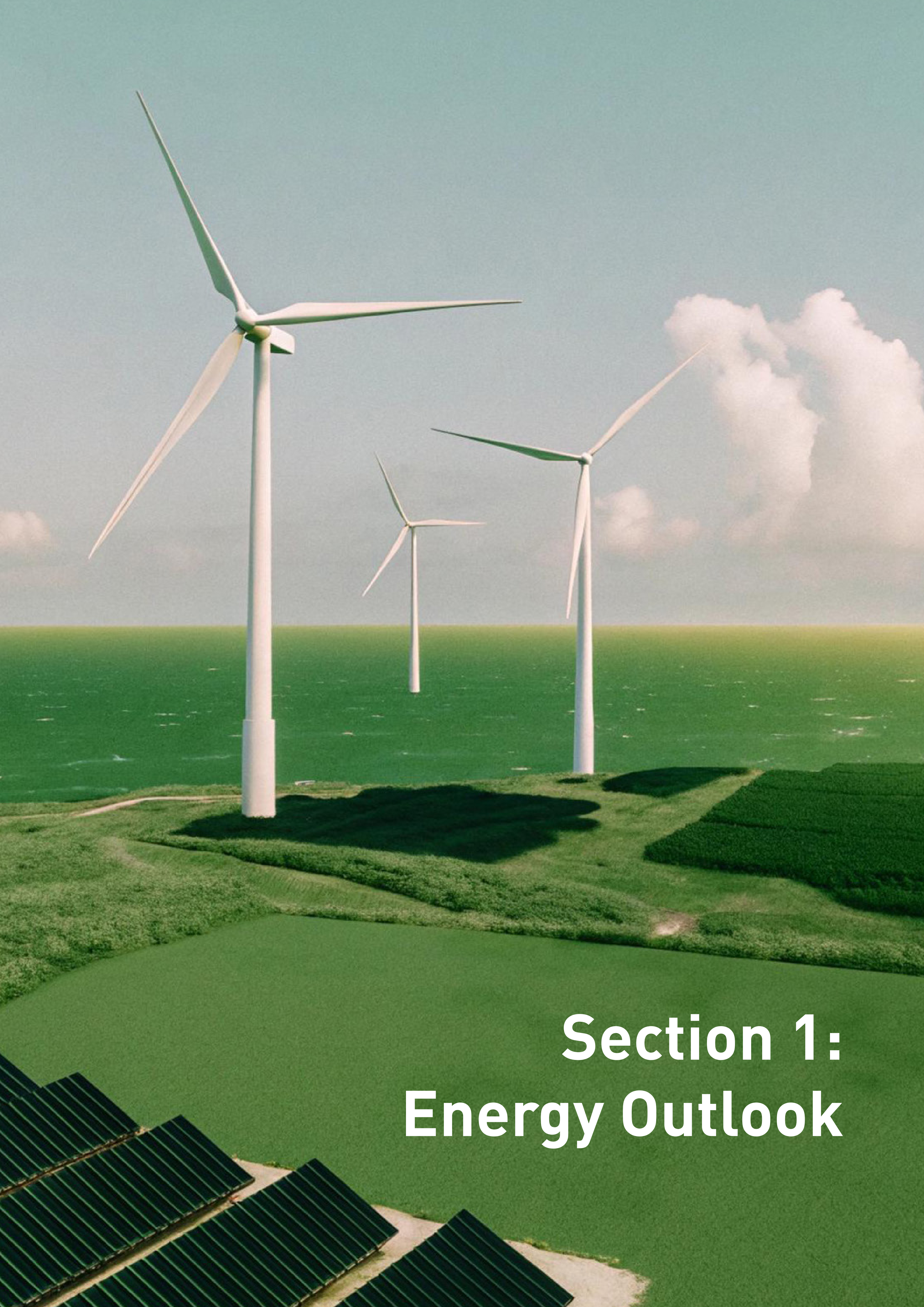
By capitalizing on these opportunities—sector coupling, local manufacturing, grid modernization, innovative financing, and regional collaboration—Pakistan can overcome current obstacles and advance toward a resilient, low-carbon energy future. In doing so, the country will strengthen its energy security, stimulate economic growth, safeguard the environment, and align with global climate objectives.

This report outlines a **Strategic Roadmap (refer to Annex IV Key Short-, Medium- & Long-Term Recommendations for Pakistan's Energy Transition)** to advance Pakistan's RE transition, categorized into short-, medium-, and long-term actions. In the short term, immediate priorities include streamlining regulatory processes through a single-window clearance system, introducing concessional financing options such as credit guarantees, and launching pilot projects for distributed energy resources (DERs). Furthermore, implementing competitive bidding frameworks for solar and wind projects is crucial to attract private investment and ensure cost efficiency.

Medium-term goals need to focus on upgrading grid infrastructure with smart grids, advanced metering, and enhanced transmission capacity in RE-rich regions, alongside developing local manufacturing capabilities for RE components through PPPs. Harmonizing federal and provincial policies will be essential to reduce project delays, while capacity-building programs for technical and regulatory stakeholders will strengthen the sector's foundation.

Over the long term, integrating sectors coupling technologies such as **Power-to-X (P2X) and Power-to-Gas (P2G)** will enhance energy flexibility and storage solutions, supporting a resilient low-carbon economy. Establishing carbon markets will create new financing pathways through carbon credit trading, while scaling domestic production of RE technologies will reduce import reliance and promote energy independence. Regional energy trade and cooperation will further position Pakistan as a leader in renewable innovation within South Asia.

Subsequent sections of the report analyze the current state of Pakistan's RE sector, including an in-depth review of energy capacity and infrastructure, policy and regulatory frameworks, emerging trends such as sector coupling and carbon markets, and a detailed case study on the adoption of solar photovoltaics (PV). Through coordinated efforts, technological innovation, and strategic investments, Pakistan can harness its abundant renewable resources to secure a cleaner, more resilient, and affordable energy future. This vision aligns with global climate objectives while enhancing energy security, industrial competitiveness, and community well-being.



Section 1: Energy Outlook

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National Energy Outlook

In the fiscal year 2022-23, Pakistan's energy mix remained heavily reliant on natural gas, oil, hydropower, coal, and nuclear energy, with a total primary energy supply of 82.62 MTOE. The supply side was primarily composed of natural gas at 23.88 MTOE (28.9%), oil at 20.11 MTOE (24.3%), and coal at 12.57 MTOE (15.2%), with hydropower contributing 8.75 MTOE (10.6%) and nuclear energy adding 6.20 MTOE (7.5%). RE sources, including solar and wind, accounted for a modest 1.39 MTOE (1.7%),

Regarding energy consumption, the electricity sector consumed 9.31 MTOE, representing approximately 11.3% of the total primary energy supply. However, significant energy losses occurred, with 32.58 MTOE (39.4%) of the total supply being lost in transformations and transmissions, including 26.03 MTOE (31.5%) in transformation losses and 5.94 MTOE (7.2%) in transmission and distribution losses. These losses underline the inefficiency within the energy system, particularly in conversion and delivery of energy (HDIP 2023).

Table 1: Electricity Generation by Sources

Source	2017-2018 (GWh)	2023-24 (GWh)	ACGR (%)
Hydel	27,925	29,167.10	5.6
Thermal	89,614	42,249.20	-4.6
Nuclear	9,880	16,753.70	21.3
Variable Renewable Energy (Wind + Solar + Bagasse)	2,314.20 + 964.25 + 578.55	4171.43 + 834.29 + 834	8.7

Source: NEPRA

The electricity generation and installed capacity in Pakistan have undergone significant changes over the years, reflecting shifts in energy policy, demand dynamics, and resource availability. To further illustrate this shift, Figure 1 depicts the installed electricity capacity by source, showcasing the dominance of thermal sources while emphasizing the growing, yet relatively small, share of renewable energy in the overall mix.

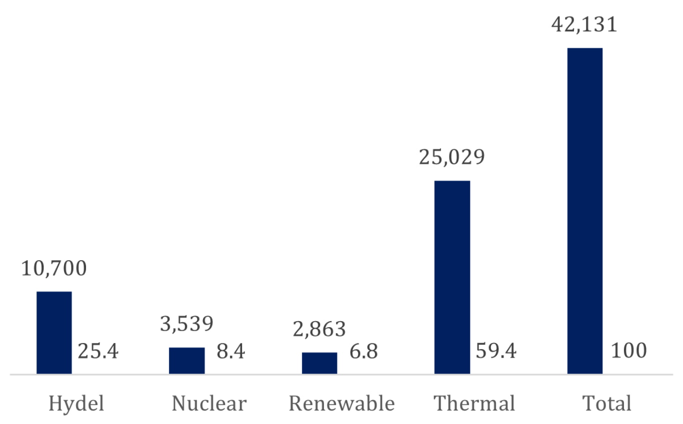


Figure 1: Installed Electricity Capacity (MW) by Source

The energy mix shown in Figure 2 underscores the reliance on hydropower and RLNG as primary sources of electricity generation in FY 2024, collectively contributing nearly half of the total power output. While coal and nuclear energy also play significant roles, the limited share of renewable sources such as wind and solar highlights the need for accelerated investments in clean energy technologies to diversify Pakistan's energy portfolio further.

Figure 2: Distribution of Power Generation by Source (in %) – FY 2024

The energy generation mix directly influences the patterns of electricity consumption across sectors. A diverse generation portfolio can ensure a more balanced and reliable energy supply, catering to the varying needs of domestic, industrial, and agricultural users. However, the current reliance on specific energy sources poses challenges in addressing the rising demand from key sectors, necessitating a closer look at consumption dynamics to identify areas where efficiency gains can be achieved.

Figure 3 shifts the perspective to electricity consumption patterns by sector for FY 2023-24. The domestic sector emerges as the largest consumer, reflecting the increasing energy demands of a growing population. The industrial and agricultural sectors, though comparatively smaller, are critical to the country's economic stability. This sectoral breakdown offers valuable insights into where energy efficiency interventions and demand-side management strategies could have the greatest impact.

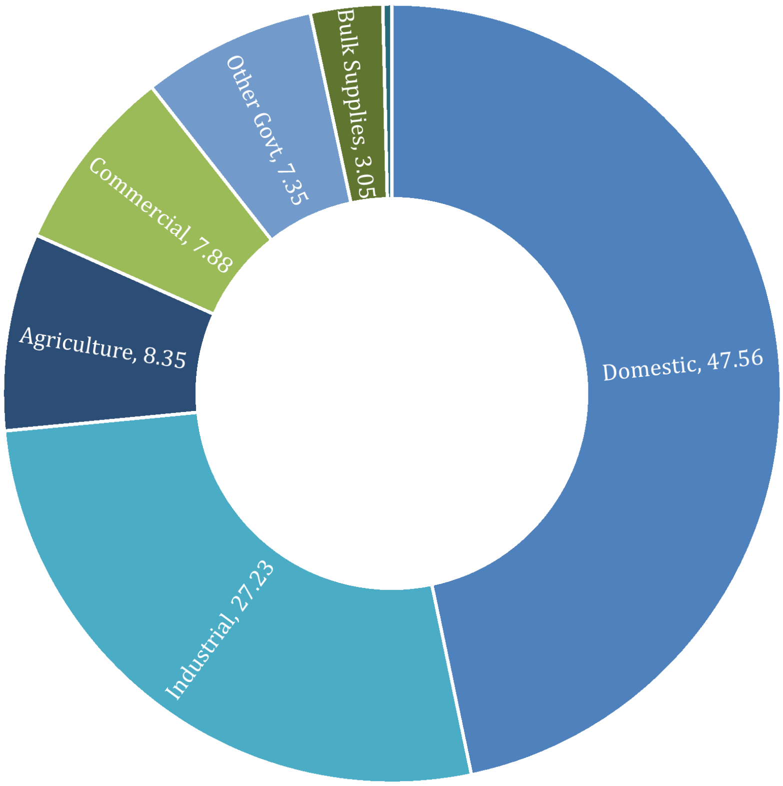


Figure 3: Electricity Consumption by Sector (in %) for FY 2023-24

Moreover, the overall electricity consumption has witnessed a consistent upward trend over the years, as depicted in Figure 4. This growth underscores the rising demand across all sectors, driven by population growth, economic activities, and infrastructure development.

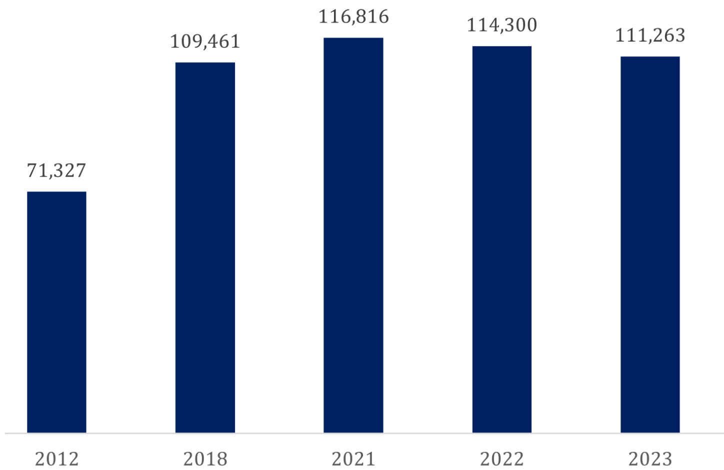


Figure 4: Electricity Consumption Trend (GWh) Over the Years

Renewable Energy Outlook

Pakistan has witnessed an 84.7% increase in generation capacity over the last ten years, which has helped bridge the energy demand-supply shortfall. In FY2023, a total of 12 generation licenses were issued by the National Electric Power

Regulatory Authority (NEPRA) across various technologies, as summarized in Table 2. Solar energy projects accounted for five licenses with a combined capacity of 7.62 megawatts (MW). Furthermore, two licenses were issued for microgrid projects, adding 1.32 MW to the overall capacity.

Table 2: Power Generation Sector-Wise Licenses Granted by NEPRA

Technology	No. of Licenses	Capacity (MW)
Solar	5	7.62
Micro Grid	2	1.3215

Source: National Electric Power Regulatory Authority

The dynamics of Pakistan's energy sector are evolving, with a notable shift in capacity additions across various energy sources. The focus remains on meeting growing energy demands while addressing infrastructural and technological challenges to optimize energy generation and distribution. The trends highlight the importance of leveraging available resources efficiently to ensure reliable energy supply across sectors.

Figure 5 provides an in-depth view of the renewable energy capacity expansion from 2022 to 2024, detailing the contributions of wind, solar, and bagasse. The data reflects the progress in utilizing diverse energy sources to strengthen the overall energy mix and enhance capacity across the country.

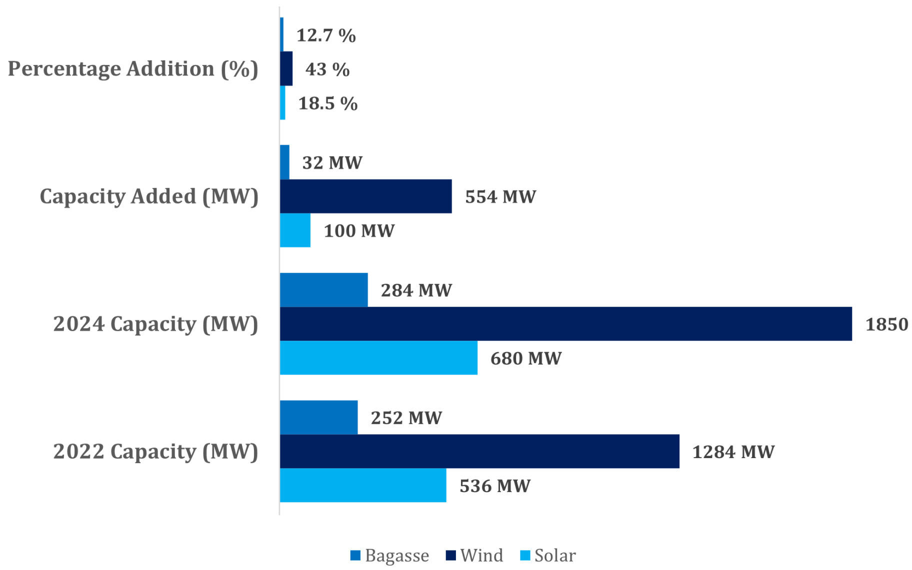


Figure 5: Breakdown of Renewable Energy Capacity Expansion in Pakistan (MW)

Investment in Renewable Energy

The Private Power and Infrastructure Board (PPIB) successfully facilitated the development of 100 Independent Power Producers (IPPs) with a total capacity of approximately 24,958 megawatts (MW), accounting for more than half of the country's total installed capacity (refer to Table 3). This attracted Foreign Direct Investment (FDI) of over USD 33 billion.

Table 3: Power Projects under Facilitation by PPIB			
Year/Description	No. of IPPs	Fuels	Power Generation (MW)
2024	3	Bagasse, Solar (32+100)	132
2025	6	Solar	132
2026	3	Wind	100

Source: : Private Power and Infrastructure Board

In addition to the commissioning of these 100 IPPs, five additional multi-fuel-based IPPs with a combined capacity of 1,066 MW are in the advanced stages of construction and are expected to be completed during 2024-25. This progress underscores the critical role of PPIB and IPPs in expanding (refer to Table 4) and stabilizing the country's power sector.

Table 4: Renewable Energy Projects in the Pipeline (MW) – Projected Capacity Additions			
Generation Type	2024	2025	2026
Wind	-	-	100
Solar	100	132	-
Bagasse	32	-	-

Source: : Private Power and Infrastructure Board

As illustrated in Figure 6, wind energy contributes 1,845 MW, accounting for 7% of Pakistan's total installed capacity, while solar energy provides 680 MW (3%), and bagasse, a bioenergy source, adds 259 MW (1%). These figures reflect Pakistan's growing reliance on RE sources.

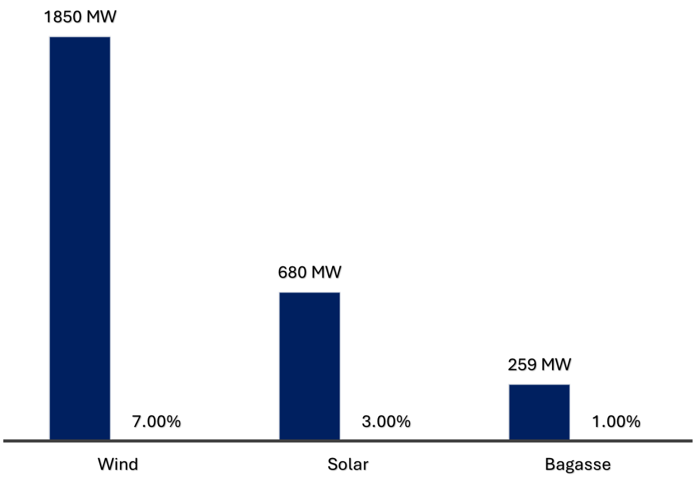


Figure 6: Contribution and Percentage Increase in VRE Sources to Pakistan's Total Capacity (MW) as of FY2024

In FY2024-25, the government's commitment to expanding RE is further underscored by substantial budgetary allocations and strategic investments aimed at enhancing energy security and transitioning towards sustainable sources. As shown in Table 5, the increased budgetary allocations for the energy sector demonstrate the government's intensified focus on strengthening this critical area compared to the previous fiscal year (Finance Division 2024):

Table 5: Budgetary Allocations for RE Energy Sector (FY2024-25)		
Category	FY 2023-24 Allocations	FY 2024-25 Allocations
Total Energy Sector Budget	PKR 9.2 billion	PKR 12.9 billion
Wind and Solar Projects	PKR 1.2 billion	PKR 1.8 billion
Energy Storage & Infrastructure	PKR 1.6 billion	PKR 2.1 billion

Source: Finance Division

Table 6 presents the projected contributions from variable RE sources, highlighting their expected role in the country's energy transition:

Table 6: Projected Variable RE Contributions		
Energy Type	2024 Capacity (MW)	Projected 2030 Capacity (MW)
Solar PV	1,240	5,539
Wind Energy	1,850	6,000
Biomass/Biofuel	430	500

Source: : Private Power and Infrastructure Board

Figure 7 highlights key financial initiatives to promote RE in Pakistan, including PKR 1 billion in subsidized loans for solar installations, PKR 500 million in tax exemptions for solar equipment, and PKR 700 million allocated through green sukuks for wind and solar projects in Punjab and Sindh. These measures aim to reduce costs, encourage adoption, and enhance financing for sustainable energy projects:

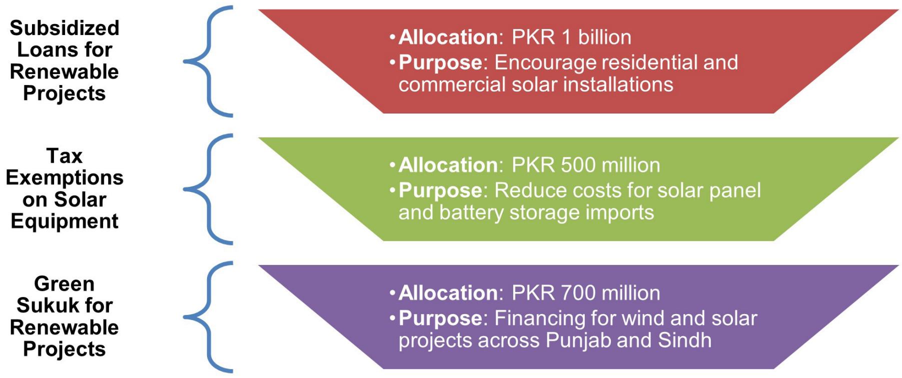
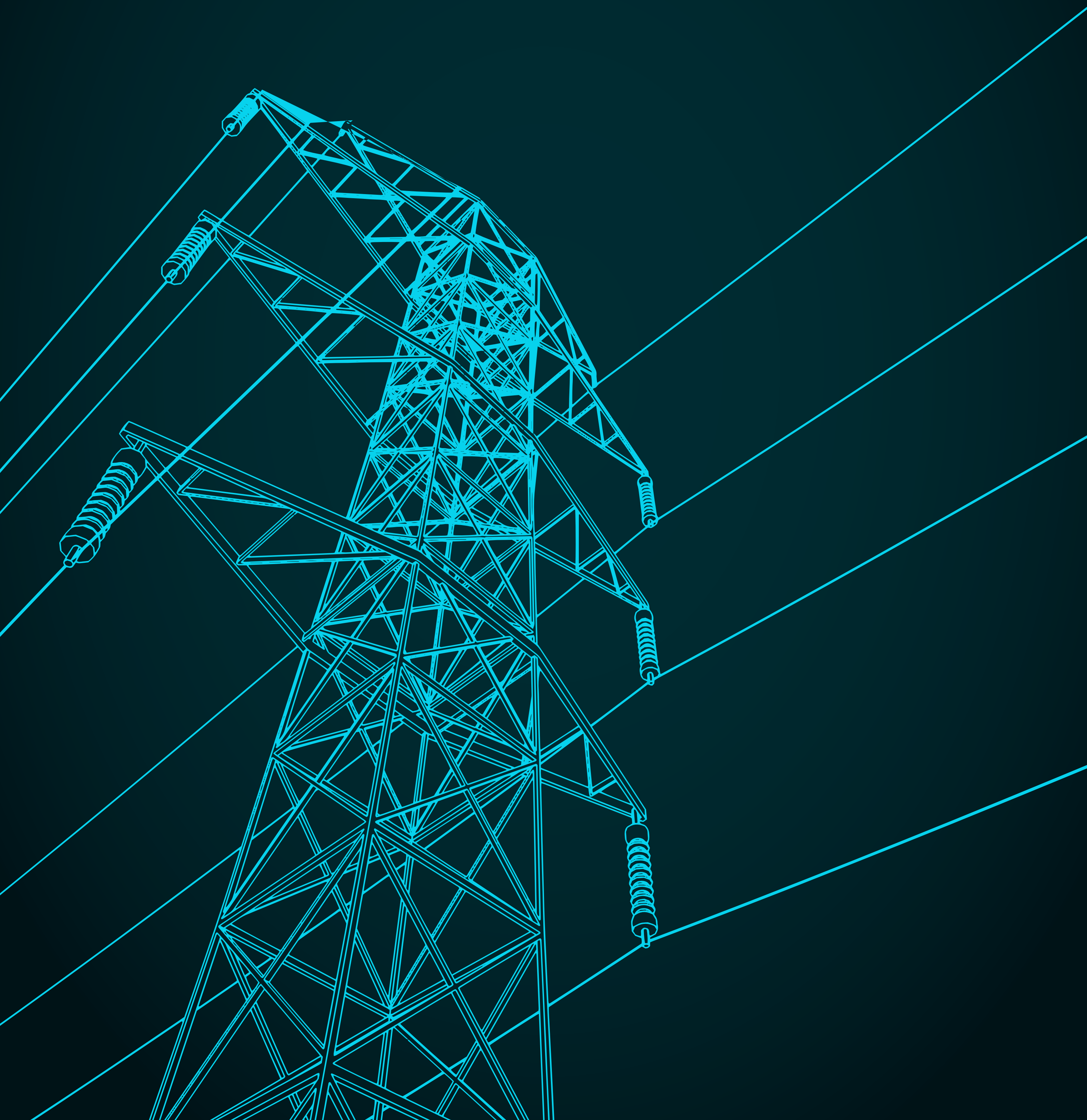


Figure 7: Budgetary Allocations for Incentive Programs of RE Projects in Pakistan (FY2024-25)

Section 2:
Power Sector Reforms



SECTION 2: Power Sector Reforms

Pakistan's power sector has seen considerable restructuring in recent years, with reforms aiming to foster a competitive, efficient, and sustainable energy market. The introduction of the National Electricity Plan, 2023-27 marks a strategic initiative aimed at modernizing infrastructure, promoting cleaner energy sources, and establishing frameworks for efficient power delivery. To complement these goals, the 2022 Fast Track Solar PV Initiatives aimed to accelerate solar installations, supporting both large-scale and residential projects to diversify Pakistan's energy mix. The plan also incorporates robust data accessibility requirements to ensure transparency, with NEPRA directing the National Transmission & Despatch Company (NTDC) to improve forecasting and optimization processes based on realistic demand and supply assessments.

This section of the report focuses on Pakistan's efforts to modernize its energy infrastructure, enhance efficiency, and promote sustainable energy development. It reviews key plans like the National Electricity Plan (2023-2027), Integrated Generation Capacity Expansion Plan (IGCEP 2024-2034), and Transmission System Expansion Plan (TSEP 2024-2034), highlighting their roles in fostering a competitive energy market (refer to Annex III and Annex V) . It also highlights case studies, including Competitive Trading Bilateral Contract Market (CTBCM); Peer-to-Peer (P2P) Energy Trading; K-Electric's RE projects; green financing mechanisms; and agrivoltaics, showcasing innovative approaches to expand RE integration, streamline regulations, and strengthen grid infrastructure to meet future energy demands.

Competitive Trading Bilateral Contract Market (CTBCM)

Approved by the Council of Common Interests (CCI) in 2023, CTBCM represents a transformative step toward a market-driven energy sector. Under this framework, large industrial consumers with demand exceeding 1 MW can establish direct contracts with power producers, moving away from the single-buyer model. This transition is expected to lower generation costs by up to 20% for bulk consumers while fostering private sector investment. To support this shift, substantial infrastructure upgrades are underway, such as the PKR 500 billion allocated for the Matiari-Lahore transmission line to prepare the grid for competitive operations.

Peer-to-Peer (P2P) Energy Trading

While CTBCM primarily facilitates direct contracts between large-scale consumers and producers, P2P energy trading extends these principles to smaller players like households and small businesses. It is an innovative model that enables small-scale energy producers and consumers to trade electricity directly, bypassing traditional intermediaries. This system operates through an interconnected platform, effectively functioning as an online marketplace where participants can set and negotiate prices based on real-time supply and demand (see Figure 8). Studies like the RENeW Nexus project trial in Fremantle, Australia, have demonstrated the potential of P2P trading. From December 2018 to January 2020, 48 households participated in rooftop solar energy trading via Powerledger's blockchain platform (Powerledger 2020). The trial showed that consumers could shift energy usage in response to price signals, reducing peak demand by up to 15%. Participants with battery storage systems (10–15 kWh) achieved faster returns on investment, reducing payback periods to under six years and encouraging broader adoption of decentralized energy solutions (IRENA 2020). P2P trading also promotes cost-competitive electricity pricing and facilitates energy autonomy. By reducing transaction costs and eliminating intermediary fees, this model creates a more inclusive and efficient marketplace. Platforms designed for P2P trading empower consumers, enabling communities with significant battery adoption to achieve up to 68% energy self-sufficiency.

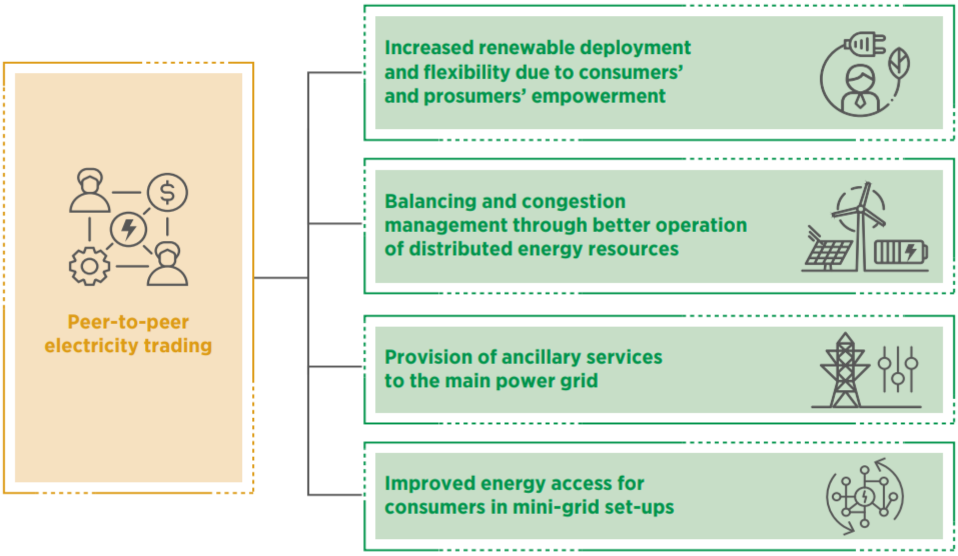


Figure 8: Impacts of P2P Electricity Trading (Source: IRENA 2020.)

Box 1 | Case Study I: P2P and Pakistan

Within the framework of Pakistan's CTBCM, P2P energy trading could significantly enhance market participation, particularly for households and small businesses. This model aligns with the CTBCM's objectives of creating a cost-efficient, transparent, and diversified energy market. P2P trading could encourage localized price discovery, allowing participants to adjust pricing based on real-time supply and demand conditions. Such mechanisms have the potential to reduce generation costs by up to 20% for bulk consumers, including large industrial entities engaged in direct contracts. P2P trading incentivizes continued grid connectivity, which is vital for managing the growing electricity demand and integrating decentralized sources such as rooftop solar systems. This aligns with Pakistan's renewable energy targets under the IGCEP 2024-34, which envisions 10% of the generation mix being derived from Variable Renewable Energy (VRE), including wind and solar, by 2034. The inclusion of prosumers—households and businesses that produce and consume electricity—could play a pivotal role in achieving this goal. By allowing prosumers to sell surplus solar energy, P2P trading promotes the adoption of renewables while enhancing energy security and cost efficiency. The government's commitment to grid modernization supports the deployment of P2P trading. For instance, investments of PKR 500 billion (approximately USD 1.8 billion) in transmission upgrades, including the Matiari-Lahore transmission line under the China-Pakistan Economic Corridor (CPEC), are vital for managing the increased complexity introduced by distributed energy sources and P2P trading platforms. These enhancements ensure that the grid can handle the bidirectional energy flows characteristic of decentralized energy trading. P2P trading also aligns with Pakistan's broader vision for renewable energy by lowering barriers to entry and transaction costs, encouraging wider market participation. By complementing the CTBCM framework, P2P trading can improve grid stability, increase renewable energy adoption, and foster a responsive energy market. As demonstrated by the RENeW Nexus trial, such platforms not only empower consumers but also support the development of a flexible and resilient energy system. In Pakistan, P2P trading has the potential to drive progress toward its renewable energy goals, enhance consumer autonomy, and contribute to a sustainable and cost-effective energy future.

Fast Track Solar PV Initiatives 2022

Accelerating Solar Deployment for Immediate Impact

As of March 2024, Pakistan added approximately 200 MW of new solar capacity under the Fast Track Solar PV Initiatives 2022, with an additional 300 MW slated for completion by 2025 (Finance Division, Government of Pakistan, 2024). A defining feature of this initiative is its focus on competitive bidding and transparent procurement processes, which have significantly reduced project costs. The average cost of solar power generation in Pakistan has dropped to USD 0.04 per kWh, positioning solar as one of the most affordable energy sources in the country. This affordability has driven a 25% increase in rooftop solar installations between 2022 and 2024, contributing around 80 MW of capacity to the national grid (National Electric Power Regulatory Authority, 2024).

Another critical aspect of the Fast Track Solar PV Initiatives (see Table 7) is the focus on public sector solarization projects. Under this program, solar PV systems have been installed on government buildings, educational institutions, and healthcare facilities, providing a reliable and cost-effective source of energy for essential services. For instance, in Sindh and Punjab provinces, over 100 government facilities were equipped with solar PV systems by early 2024, generating a combined capacity of 50 MW (National Electric Power Regulatory Authority, 2024). These installations have not only reduced operational costs for public institutions but have also demonstrated the viability of large-scale solar deployment in urban and semi-urban areas

Table 7: Public Sector Solarization Projects under the Fast Track Solar PV Initiatives

Province	Number of Facilities	Installed Capacity (MW)	Key Sectors
Sindh	60	30	Government buildings, schools
Punjab	40	20	Healthcare facilities, offices
Total	100	50	

Source: National Electric Power Regulatory Authority

Such Initiatives are also expected to deliver substantial environmental and social benefits. It is projected to reduce carbon emissions by over 500,000 tonnes annually, supporting Pakistan's commitments under the Paris Agreement (UNDP 2022). Furthermore, the adoption of solar energy has expanded energy access for off-grid communities, particularly in Balochistan and Sindh, where rural electrification rates lag behind the national average. Solar mini grids established in these regions now provide reliable electricity to over 50,000 households, significantly improving living standards and fostering socioeconomic development (IRENA 2022).

National Electricity Plan 2023-27

Laying the Groundwork for Renewable Energy Integration and Grid Modernization

The National Electricity Plan 2023-27 provides a strategic framework to tackle Pakistan's energy challenges by integrating RE, modernizing grid infrastructure, and improving operational efficiencies. It prioritizes Distributed Energy Resources (DERs) like solar and wind, regulatory transparency, and advanced forecasting to align the energy sector with sustainability goals. Figure 9 outlines the plan's key initiatives and progress, including DER integration, enhancements in demand forecasting, and regulatory measures to support RE investments.

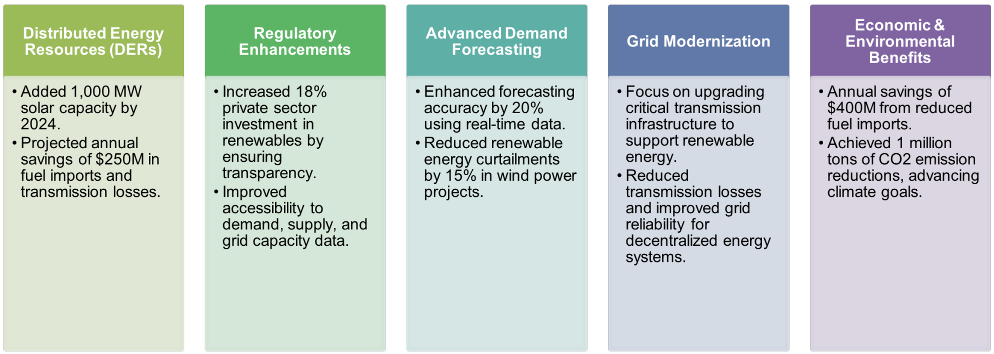


Figure 9: National Electricity Plan 2023-27: Key Developments at a Glance

By focusing on grid reliability, RE adoption, and transparent investment practices, the plan is reshaping Pakistan's energy landscape. Environmentally, the integration of renewables is expected to reduce greenhouse gas emissions by over 1 million tonnes annually, contributing to the national goal of cutting the carbon footprint by 20% by 2030. Despite these advances, challenges remain, particularly in financing large-scale grid upgrades and ensuring the timely execution of transmission projects essential for RE integration. To address these gaps, the government is actively pursuing international partnerships and development funds. Recent discussions have highlighted potential loan agreements with international agencies, including the World Bank, to support climate-friendly infrastructure investments (World Bank 2024).

Integrated Generation Capacity Expansion Plan (IGCEP) 2024-2034

Charting the Future of Renewable Energy in Pakistan

The latest Integrated Generation Capacity Expansion Plan (IGCEP) 2024-34 introduces a transformative strategy for Pakistan's power sector, stressing RE integration and increased reliance on indigenous resources. Developed by the NTDC, the plan projects an increase in total installed capacity from 42,000 MW in 2024 to approximately 57,000 MW by 2034, driven by a 46% rise in electricity demand. This growth is attributed to expanding industrial activity and household consumption. With an estimated investment of USD 72 billion (Table 8)—double that of prior IGCEPs—the plan marks a significant departure from earlier strategies (see Annex VI-Table 8), shifting focus away from imported fuels like RLNG and coal to renewable and indigenous sources.

Table 8: Investment Allocation in IGCEP 2024-34 by Category

Investment Focus	Budget Allocation ($ Billion)
Generation Expansion	40
Renewable Integration	10
Grid Modernization and Storage	15
Other Infrastructure	7

RE plays a central role in IGCEP 2024-34, with 15,000 MW of new capacity planned primarily from hydropower, solar, and wind. Hydropower's share of the energy mix is projected to rise to 46% by 2034, compared to 35-40% in earlier plans. The plan also sets ambitious targets for Variable Renewable Energy (VRE), with solar PV expected to add 5,539 MW, including 2,107 MW from net-metered installations—nearly doubling solar capacity compared to the previous plan. Combined, solar and wind are forecasted to contribute 10% to the energy mix by 2034.

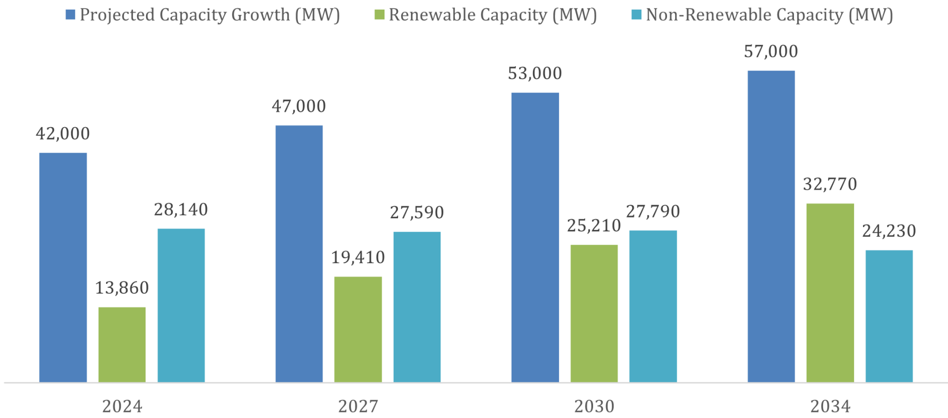


Figure 10: Projected Energy Capacity Distribution by Source: Renewable vs. Non-Renewable (IGCEP 2024-2034)

In addition to renewables, the plan includes greater reliance on local resources, including hydropower, nuclear energy, and domestic coal. Indigenous sources are projected to make up 31% of the energy mix by 2034, a significant increase from 20% in earlier plans. This shift not only promotes energy independence but also reduces exposure to volatile international energy prices, offering substantial cost savings.

To manage the integration of intermittent renewables, IGCEP 2024-34 allocates resources to grid modernization. Key initiatives include smart grid technologies, energy storage solutions, and advanced grid management systems, ensuring the seamless integration of VRE sources. These measures address challenges associated with higher VRE penetration, improving grid stability and operational efficiency. The financial aspects of IGCEP 2024-34 focus on aligning project costs with NEPRA-approved budgets to ensure the economic viability of each project.

A notable feature of the plan is the expansion of non-hydro renewables—solar, wind, and bagasse—to support Pakistan's sustainability goals. By 2034, these sources are expected to form a significant part of the energy mix, reflecting the government's commitment to cleaner energy solutions. This strategic shift toward renewables underscores Pakistan's dedication to reducing its reliance on imported fuels, achieving environmental targets, and fostering a resilient, low-carbon energy future. Table 9 outlines the projected capacities and shares of solar, wind, and bagasse for 2024, 2029, and 2034, highlighting their increasing role in Pakistan's energy landscape:

Table 9: Projected Variable RE Contributions (Excluding Hydro)in Pakistan's Energy Mix (2024-2034)

Year	Solar (MW)	Solar % of Total	Wind (MW)	Wind % of Total	Bagasse (MW)	Bagasse % of Total	Total Non-Hydro Renewables (MW)	Total % of Capacity
2024	1,124	2.7	6,431	15.3	1,064	2.5	8,619	20.5
2029	7,523	16.0	6,521	13.9	2,109	4.5	16,153	21
2034	9,072	15.9	6,219	10.9	4,018	7.0	19,309	22

Solar, wind, and bagasse are set to play a pivotal role in diversifying the energy mix, with total non-hydro renewable capacity projected to grow significantly by 2034. As depicted in Figure 11, this growth underscores the country's transition toward a more sustainable energy future, showcasing the progressive contributions of each renewable energy source to the overall capacity for the years 2024, 2029, and 2034.

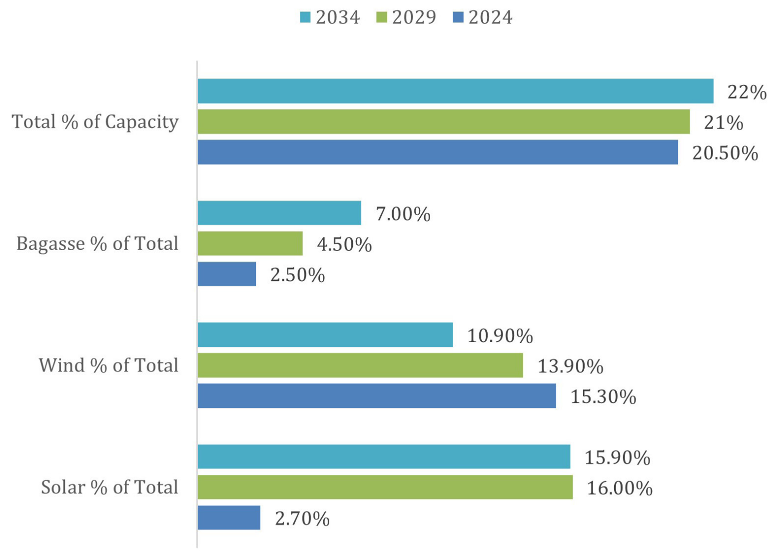


Figure 11: Projected Non-Hydro Renewable Energy Contributions to Pakistan's Total Capacity (2024, 2029, 2034)

Transmission System Expansion Plan (TSEP) 2024-2034

Building Infrastructure for Renewable Energy Integration

After the finalization of IGCEP 2024, the NTDC introduced the Transmission System Expansion Plan (TSEP) 2024-2034, focusing on expanding transmission infrastructure to support existing and forecasted power generation needs across sectors through 2034. The plan includes the development of transmission lines, substations, and generation interconnection systems for mega projects, ensuring improved grid performance and reliability.

A key feature of TSEP 2024-34 is the establishment of dedicated transmission corridors for RE projects in regions with high solar and wind potential, such as Sindh, Balochistan, and southern Punjab. These corridors aim to efficiently evacuate power from large-scale RE projects, reducing system losses and enhancing grid stability. By 2024, NTDC had initiated high-capacity transmission lines for wind farms in Jhimpir, Sindh, which collectively contribute over 1,200 MW to the national grid (NTDC 2024). The plan also prioritizes the connection of RE hubs to major load centers like Karachi, Lahore, and Islamabad. Key projects under TSEP include (Table 10):

Table 10: Key Projects under TSEP

Project Name	Voltage Level	Region	Capacity (MW)	Estimated Cost (USD)
Matiari-Moro-RYK Transmission	765 kV	Sindh-South Punjab	3,000	1.8 billion
Thar-Gharo Line	500 kV	Jhimpir-Gharo Corridor	2,500	950 million

These projects are designed to accommodate an additional 7,000 MW of renewable capacity by 2034. However, financial constraints have caused implementation delays, posing a significant challenge to the plan's execution.

To address the intermittency of RE, TSEP also calls for the adoption of Battery Energy Storage Systems (BESS). Pilot projects with a combined capacity of 200 MWh have been proposed, including:

- **Jhimpir Wind Corridor:** A 50 MWh BESS to store surplus wind energy during off-peak hours.
- **Balochistan Solar Integration:** A 100 MWh BESS to support grid stability for solar farms.

The estimated investment in BESS is USD 400 million over five years, with the government seeking international partnerships for technology transfer and funding.

Renewable Energy Developments in Pakistan

Pakistan is steadily developing its RE sector, with initiatives in solar, wind, and waste-to-energy projects. By leveraging indigenous resources and gradually reducing dependence on imported fuels, the country aims to improve energy security and promote long-term sustainability. A number of key RE projects in Pakistan are either completed or close to completion, demonstrating effective collaboration between public and private sectors. These projects play a critical role in addressing Pakistan's increasing energy needs while contributing to a more sustainable and environmentally responsible energy future.

Solar and Biogasse

To further enhance solar distribution, the government has introduced Solar PV Generation on 11 kV Feeders. This initiative integrates medium-scale solar PV installations directly into the medium-voltage network, addressing local power quality issues without extensive infrastructure upgrades. With a planned capacity of 2,000 MW, each project is capped at 4 MW, ensuring cost efficiency through competitive bidding. This initiative targets an additional 6,000 MW of solar PV capacity, with three major projects leading the way:

- **Kot Addu/Muzaffargarh Project:** 600 MWp capacity
- **Jhang Solar Project:** 600 MWp capacity
- **Layyah Solar Project:** 1,200 MWp capacity

In 2015, Pakistan introduced its Net Metering Policy under the Distributed Generation and Net Metering Regulations. The policy allows grid-connected consumers with RE installations ranging from 1 kW to 1 MW to offset their electricity bills by exporting surplus energy to the grid. Subsequent amendments, such as extending distributed generation license durations and exempting systems under 25 kW from licensing requirements, have boosted adoption significantly. As a result, installed net-metered capacity grew from 1,055 MW in June 2023 to 2,000 MW by April 2024 (refer to Figure 12).

Despite its success, this rapid expansion has created challenges for distribution companies (DISCOs), prompting regulatory adjustments. A proposed shift to a gross billing model aims to balance consumer benefits with DISCO financial sustainability. Measures under consideration include reducing buyback rates, encouraging higher self-consumption through shorter net-off cycles, and promoting battery storage adoption to optimize energy use.

To address technical challenges like voltage fluctuations and grid instability, upgrades such as smart meters and GIS-based grid analysis are being implemented. These improvements aim to enhance grid reliability and accommodate the growing share of distributed generation. International stakeholders, including the Asian Development Bank (ADB), are actively supporting these reforms to ensure the long-term resilience and sustainability of Pakistan's net metering framework.

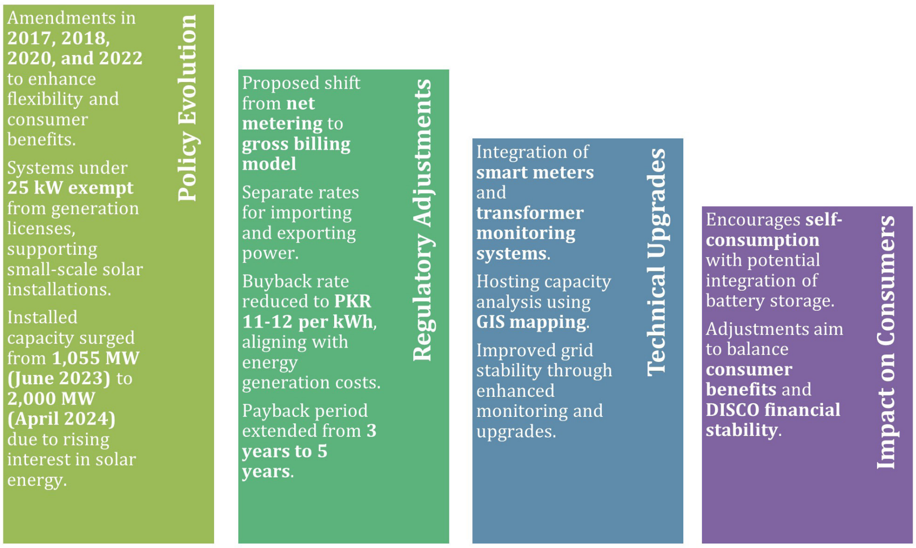


Figure 12: Net Metering Policy: Evolution and Milestones

Other solar and bagasse-based projects that have been gaining momentum include:

Table 11: Solar and Bagasse Projects 2024

Project	Description	Status
Scatec Solar Projects	Three solar power plants (50 MW each) established by Scatec ASA in Sukkur, expedited by PPIB for COD.	Achieved COD
Shah Taj Sugar Mills (Bagasse)	A 32 MW bagasse-based plant in Mandi Bahauddin, with PPIB facilitation.	Under construction
Net Metering Installations	As of March 2024, 117,807 net-metered solar installations, totaling 1,822 MW capacity, with 400+ certified installers.	Continuous growth

Wind

Wind energy currently contributes approximately 4% to Pakistan's total electricity generation, with significant potential for expansion. The country has an estimated capacity to generate up to 340 GW of wind energy, primarily in high-potential regions such as Sindh and Balochistan. Ongoing wind projects align with Pakistan's strategy to diversify its energy mix and increase the share of RE. Key developments include

Table 12: Wind Energy Development			
Project	Location	Capacity	Status
Gharo Wind Farm	Sindh	50 MW	Under construction
Gujju, Thatta Wind Project	Sindh	14 MW	Assessment phase
Jhimpir Wind Projects	Sindh	50 MW, 50 MW, 51 MW	Assessment phase

Box 2 | Case Study II: K-Electric's Renewable Energy Initiatives

K-Electric (KE) is reshaping Pakistan's RE landscape through innovative projects that prioritize efficiency, cost competitiveness, and sustainability. With a target to achieve a 30% RE share in its generation mix by 2030, KE is integrating solar, wind, and hybrid technologies to meet growing energy demands while reducing reliance on imported fossil fuels.

In a landmark development, KE secured Pakistan's lowest-ever tariff for RE with a 150 MW solar project in Balochistan, achieving a rate of PKR 11.2 per unit through competitive bidding. This milestone highlights KE's ability to leverage private sector investments for delivering affordable and sustainable energy solutions. The project is a critical component of KE's broader plan to deploy 1,300 MW of renewable capacity across regions like Sindh and Balochistan.

KE further advanced its renewable strategy with the launch of Pakistan's first 220 MW hybrid wind-solar project in Dhabeji, Sindh. This initiative attracted seven international bids, with Canadian firm JCM Power winning at a record-low tariff of PKR 8.9189 per unit. By combining wind and solar technologies, this hybrid model optimizes energy generation efficiency and cost-effectiveness, setting a benchmark for future renewable projects in Pakistan. These efforts diversify KE's energy portfolio while enhancing grid reliability and energy security.

Beyond individual projects, KE has developed a robust pipeline of 640 MW in solar and hybrid technologies. Supported by transparent bidding processes approved by NEPRA, these initiatives have attracted local and international investors, reflecting growing confidence in Pakistan's RE potential. KE's ongoing efforts, including hybrid projects in Winder and Bela, underscore its commitment to transforming Pakistan's energy sector through sustainable and cost-efficient models.

Waste-to-Energy Initiatives

NEPRA has also issued the first license for a 40 MW waste-to-energy plant in central Pakistan, designed to process approximately 2,000 tonnes of solid waste daily. This project provides dual benefits by addressing waste management challenges and contributing to RE generation. Similar projects are under consideration for Sindh and Punjab, showcasing the potential to scale waste-to-energy solutions across the country.

Despite ongoing reforms, Pakistan's RE integration remains insufficient. National plans like the IGCEP 2024-34 and the TSEP 2024-34 are focused on hydropower and thermal energy, with limited prioritization of wind and solar projects.

Box 3 | Case Study III: Catalyzing Renewable Energy Growth in Pakistan

In 2023, Pakistan's RE sector made significant strides in green financing, reinforcing its commitment to sustainable energy goals. A key development was expansion of the green bond market, led by the Water and Power Development Authority (WAPDA). Building on its USD 500 million green bond issued in 2021, which funded hydropower projects like the Diamer-Bhasha and Mohmand dams, WAPDA has continued leveraging these funds to enhance energy generation from sustainable sources. These bonds, adhering to international standards such as the Green Bond Principles, attracted global investors, including the World Bank and ADB.

In 2023, the Securities and Exchange Commission of Pakistan (SECP) updated its guidelines for green bonds to align with international best practices, ensuring transparency and accountability in fund allocation. These guidelines aim to attract international investors and support initiatives across renewable energy, sustainable agriculture, and water management.

The ADB and World Bank have also been instrumental in financing RE projects in Pakistan. The ADB committed USD 9.8 billion for climate action in the Asia-Pacific region in 2023, with a portion allocated to Pakistan's solar and wind infrastructure. Similarly, the World Bank approved USD 350 million in financing to enhance fiscal management and link funding to sustainable energy expansion. These contributions support Pakistan's broader goal of achieving a 30% renewable share in its energy mix by 2030.

Pakistan has also embraced innovative financing models like green sukuks (Islamic green bonds), designed to attract investments from the Middle East and international markets. Green sukuks were announced in 2023, reflecting a diversified approach to green financing that appeals to various investor profiles. The International Finance Corporation (IFC) reported a 7.1% annual growth in green bond issuance in emerging markets like Pakistan, highlighting strong investor interest.

Pakistan's focus on green financing supports the expansion of its renewable capacity, targeting projects in solar and wind. These initiatives align with the national strategy to integrate sustainable financing into energy policy, demonstrating a proactive approach to achieving the 2030 renewable energy targets.

Box 4 | Case Study IV: Agrivoltaics: Bridging Agriculture and Renewable Energy in Pakistan

Agrivoltaics, the integration of solar panels with agricultural practices, is emerging as a promising solution in Pakistan's RE sector. Recent initiatives highlight its potential in enhancing both energy generation and agricultural productivity, particularly in regions facing water scarcity and extreme weather conditions. The approach combines the use of solar panels installed above crops or grazing lands, which not only generates electricity but also provides partial shade that benefits crop growth. This dual-use model maximizes land efficiency and is increasingly relevant as Pakistan seeks innovative ways to meet its energy and food security needs

In 2023, several pilot agrivoltaics projects were launched across Punjab and Sindh. These projects, supported by international organizations like the United Nations Industrial Development Organization (UNIDO) and partnerships with local agricultural departments, aim to evaluate the effectiveness of combining solar panels with the cultivation of crops such as wheat, vegetables, and sugarcane. For instance, in Rahim Yar Khan, farmers who transitioned to solar-powered irrigation systems have reported up to a 30% increase in crop yields and reduced energy costs due to the dual-income potential of producing and selling surplus electricity back to the grid

Furthermore, these projects have demonstrated significant water conservation benefits. Solar panels provide shading that reduces evaporation rates by 20-30%, a critical advantage in Pakistan's arid regions like Baluchistan. The government, through the Alternative Renewable Energy (ARE) Policy, 2019, has recognized the value of agrivoltaics and is encouraging further investments and scaling of these projects as part of the broader RE strategy

With the expansion of agrivoltaics systems, Pakistan is not only enhancing its renewable energy capacity but also supporting rural economies by offering farmers additional revenue streams. The ongoing research and collaboration with international partners signal a strong commitment to making agrivoltaics a cornerstone of Pakistan's sustainable development efforts in the coming years.

The RE sector faces several challenges:

- Policies such as reduced net metering buyback rates have created uncertainty in the rooftop solar market, slowing the adoption of distributed solar systems—a key driver of growth under the Fast Track Solar PV Initiatives 2022.
- Bureaucratic inefficiencies prolong the development of RE projects, deterring private investment.
- The absence of robust local manufacturing capabilities for renewable technologies inflates project costs and increases vulnerability to global supply chain disruptions.
- Progress in solar and wind energy remains concentrated in specific regions, with Sindh and Balochistan leading in project deployments. However, the success of RE policies like CTBCM, IGCEP, and TSEP hinges on modernizing energy infrastructure. Technologies such as Supervisory Control and Data Acquisition (SCADA) systems and upgraded transmission corridors are critical for managing the grid's growing complexity and ensuring efficient integration of renewables.

To secure a sustainable energy future, Pakistan must address key gaps in policy implementation and align its reforms with its RE potential. This includes:

1. Prioritizing Renewables in Policy Frameworks: Greater emphasis on wind and solar projects within IGCEP and TSEP.
2. Incentivizing Local Manufacturing: Building domestic capabilities to reduce reliance on imports and improve cost efficiency.
3. Enhancing Financial Support: Providing consistent policy incentives for rooftop solar and distributed energy systems.

Section 3: Trends to Watch in Renewable Energy Development

SECTION 3: Trends to Watch in Renewable Energy Development

Introduction

In the backdrop of the global policy crisis, particularly in the developing world facing financial constraints, there is a dilemma of accessibility, affordability, and sustainability across various sectors of the economy. Policymakers around the globe are looking for integrated solutions. Similarly, in the context of Pakistan's multifaceted crisis encompassing the economy, energy, and environment (3Es), the need for integrated RE development becomes the lynchpin of the solution (The News International 2024). This section explores major trends that have the potential to transform Pakistan's RE landscape through, firstly, ***Sector Coupling,*** and secondly, ***Carbon Markets.***

A. **Sector or Power Coupling:** The integration of intermittent variable RE sources (Wind and Solar) in the electricity sector requires techniques with a higher degree of flexibility to maintain a reliable supply-demand balance (Mararakanye and Bekker 2019). In 2023, Pakistan experienced a nationwide power sector breakdown due to aging infrastructure and anomalies in system frequency (Daily Times 2024). Traditional solutions include storage mechanisms, reliable and flexible transmission networks, and demand management strategies. Currently, there is a renewed focus on "sector or power coupling," denoted as "P2X," where excess electricity is converted into other energy carriers, such as heat, transportation, and hydrogen. This approach is particularly valuable in avoiding the curtailment of wind and solar as intermittent power sources and achieving economically feasible storage through applications like power-to-vehicles (P2V) and power-to-heat (P2H) (Noussan 2022).

B. **Carbon Markets:** Carbon markets offer a means to mitigate greenhouse gas emissions by allowing entities to buy and sell carbon credits. These credits represent reductions, sequestration, or avoidance of emissions (Carbon Market Watch 2020). Carbon markets are essential in the context of Pakistan's commitment to addressing climate change and reducing emissions. There are two types of carbon markets: compliance and voluntary. Compliance markets result from regulatory requirements, while voluntary markets involve the voluntary exchange of carbon credits. The adoption of carbon trading mechanisms can incentivize investments in RE, expand the market size for clean energy technologies, and promote innovation.

Sector Coupling

Power-to-X (P2X) technologies are poised to play a significant role in Pakistan's transition toward integrated RE systems. These technologies enable both the direct utilization of RE and its conversion into other forms, such as gas, heat, and fuel, through sector coupling (Clean Energy Wire 2024). As discussed during COP28, sector coupling represents a key policy approach for achieving an orderly and just energy transition. However, the full potential of P2X technologies depends on addressing several critical dimensions like scalability, market and demand structure dynamics, and investment frameworks to ensure a reliable supply chain (Daily Times 2024; Perner and Bothe 2018):

1. **Technology Scalability:** Achieving cost reductions through scaling requires widespread adoption of cleaner alternatives and significant financial investment in these technologies over conventional fossil fuels (Noussan 2022).
2. **Policy Incentives and Market Dynamics**: Policy-driven incentives and the establishment of CO2 emissions markets are essential to catalyze business models for P2X technologies. These measures can shape future demand structures and attract investments (Mararakanye and Bekker 2019).
3. **Grid Optimization with Real-Time Co-optimization (RTC):** RTC represents a modern market approach for co-optimizing energy dispatch and ancillary services, ensuring grid reliability while enhancing cost efficiency. A notable example is the Electric Reliability Council of Texas (ERCOT), where RTC has reformed market design, reducing biases that previously favored less efficient generators. By integrating energy dispatch with ancillary services like regulation and spinning reserves, ERCOT has optimized grid operations, resulting in improved reliability and significant cost savings for consumers (Sunset Advisory Commission 2021).

Pakistan holds significant investment potential in power-to-gas, power-to-vehicles, and power-to-heat technologies. With the right policy frameworks, market incentives, and technology scaling, these P2X solutions can support Pakistan's RE goals by diversifying energy applications and enhancing grid reliability. Leveraging sector coupling technologies will be instrumental in transitioning toward a sustainable, low-carbon economy

Power to Gas (P2G)

Power-to-Gas (P2G) technology represents a transformative solution for addressing energy storage and supply challenges, particularly in countries like Pakistan, where natural gas is a critical yet depleting resource. P2G involves converting surplus renewable electricity into hydrogen or synthetic methane, which can be stored and injected into the existing natural gas infrastructure or used in sectors traditionally reliant on natural gas, such as industrial production and household heating. This technology not only aids in stabilizing the electricity grid by absorbing excess renewable power but also provides an alternative to conventional natural gas, helping to mitigate supply shortages and enhance energy security. As global energy systems shift towards decarbonization, P2G offers Pakistan a pathway to reduce dependency on fossil fuels, leverage RE resources, and address the growing natural gas deficit with a sustainable and long-term solution.

According to the International Energy Agency (IEA), approximately 25% of Pakistan's total primary energy supply is derived from natural gas, including both imported and indigenous sources (IEA 2024). The ADB notes that Pakistan's gas reserves are depleting, with 80% expected to be exhausted by 2030 (Malik et al., 2019). Furthermore, the Russia-Ukraine conflict has heightened prices for imported LNG and RLNG. These factors have precipitated a gas shortage crisis, particularly affecting households and industrial production sectors like textiles. Therefore, Pakistan presents an economically feasible case for P2G within the broader scope of P2X technologies (Noussan 2022).

Hydrogen Production and Synthetic Methane

Hydrogen production is a cornerstone of P2G technologies, encompassing both Green Hydrogen (produced via electrolysis powered by RE) and Blue Hydrogen (produced using fossil fuels). While Green Hydrogen is considered a sustainable solution, Blue Hydrogen serves as a transitional option as the energy sector moves toward decarbonization. The electrolysis process can also incorporate a methanation step to generate synthetic methane as a by-product. This additional process helps reduce net emissions, further enhancing the sustainability of hydrogen production.

Current global hydrogen production predominantly relies on fossil fuels, with 47% from natural gas, 27% from coal, 22% as an oil by-product, and only 4% from electrolysis (IRENA 2022). However, this composition is expected to shift due to initiatives like the Carbon Border Adjustment Mechanism (CBAM) by the European Union, which imposes emissions fees on imported hydrogen, incentivizing cleaner production methods. Transitioning to full reliance on hydrogen as an energy source would require approximately 4,000 terawatt-hours (TWh) of electricity, surpassing the EU's annual electricity generation, underscoring the need for a massive expansion of RE sources such as wind and solar (Benghanem et al., 2023).

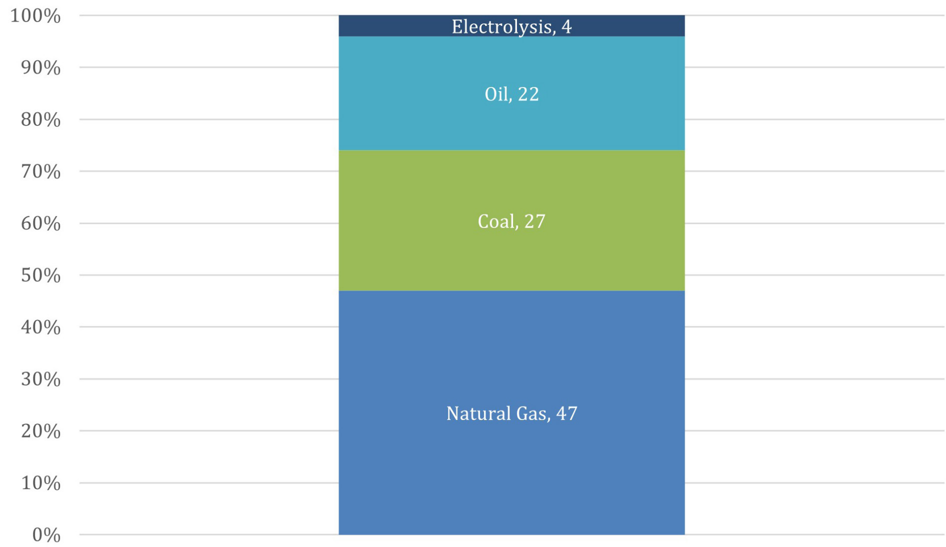


Figure 13:Hydrogen Production by Fuel Type (%)

Hydrogen production through electrolysis is currently limited by energy efficiency, which ranges from 50% to 75%, depending on the technology and load factors. Moreover, freshwater availability poses a challenge, particularly in arid regions. Utilizing seawater may require additional desalination processes, with associated costs ranging from USD 4 to USD 5 per cubic meter when employing reverse-osmosis technologies (Mohammed-Ibrahim and Moussab 2020).

The cost of hydrogen production depends on variables such as investment costs, electricity prices, and operational hours. By 2030, global hydrogen production costs are projected to range between:

- **USD 4–6 per kilogram ($/kg)** from dedicated RE sources (RES) plants.
- **USD 3–5 per kilogram ($/kg)** when drawing power from national grid systems.

Regional differences in RE potential, particularly solar and offshore wind, significantly influence cost dynamics. Offshore wind, offering higher load factors, is emerging as a compelling option for coupling with electrolysis (Benghanem et al., 2023)

The integration of CO2-methanation into hydrogen production adds a valuable dimension to P2G technologies. Current capital expenditure (CAPEX) costs for CO2-methanation stand at approximately:

- **USD 1,000 per kilowatt-electric ($/kWel)** for chemical channels.
- **USD 1,600 per kWel** for biological channels.

By 2030, these costs are projected to decrease to USD 700 per kWel and USD 800 per kWel, respectively, driven by production scaling and technological advancements (Benghanem et al., 2023).

To fully realize the potential of P2G technologies in Pakistan, a substantial expansion of RE capacity, technological scaling, and investment in infrastructure are essential. These advancements, coupled with policies like CBAM and ongoing cost reductions, position hydrogen and synthetic methane as critical drivers of a sustainable, low-carbon energy future.

Power to Heat (P2H)

In the context of Pakistan's multifaceted crisis of Economy-Energy-Environment, the concept of Power-to-Heat (P2H) emerges as a significant strategy to address the energy challenges particularly in hard-to-abate industries such as cement and steel. P2H, a technological approach that seeks to integrate the electricity and heating sectors, can potentially reduce Pakistan's dependency on traditional energy sources. According to Power System Statistics 2022, the major share of electricity consumption comes from the residential sector (about 50%) depicting industrial sector is not connected with the grid, therefore the potential for industrial sector to be integrated with electricity exist in Pakistan.

P2H in centralized systems, such as district heating, exploits low electricity prices if these systems are linked with dedicated variable RE sources such as wind and solar to generate heat, offering substantial economic advantages, particularly for a country like Pakistan (IEA 2024). In contrast, distributed P2H systems, catering to individual users, face operational and economic feasibility hurdles in Pakistan, where the winter season is relatively shorter, yet they represent an essential aspect of decentralized energy solutions. The attractiveness of P2H lies in its relatively low investment costs, relying on mature technologies like heat pumps and electric boilers (IEA 2024). However, its operational efficiency hinges on the volatility of electricity and alternative fuel prices, particularly in contexts like Pakistan, where energy prices are subject to frequent fluctuations (Mirza, Waleed and Qurat-ul-Ann 2022).

International experiences, especially from Northern European countries like Denmark, Sweden, and Norway, provide valuable lessons for Pakistan. These countries have successfully integrated P2H within their district heating networks, utilizing electric boilers and heat pumps. An analysis of market data from these regions indicates the varied effectiveness of P2H, influenced by factors such as power mix, taxation levels, and alternative energy costs. This analysis suggests that considering Pakistan's specific context, there is feasibility and potential economic impact of P2H in its unique energy market (Hu et al., 2020).
P2H also plays a crucial role in supporting the integration of RES into the heating

sector, aligning with global decarbonization goals. The potential for P2H in Pakistan is significant, given the country's abundant solar and wind energy potential (Daily Times 2024). However, barriers such as high electricity costs for end-users and a reliance on traditional fossil-fueled boilers present challenges. Policy frameworks in Pakistan may need to include incentives to encourage a shift towards more sustainable heating solutions, considering the higher initial costs of technologies like heat pumps (Hu et al., 2020).

Furthermore, the role of power aggregators and the application of time-of-use tariffs could enhance the efficiency of small-scale P2H systems, especially in residential settings. These measures could optimize the operation of heat pumps, aligning their usage with periods of low electricity demand or high RE generation, thus contributing to a more balanced and efficient energy system in Pakistan.

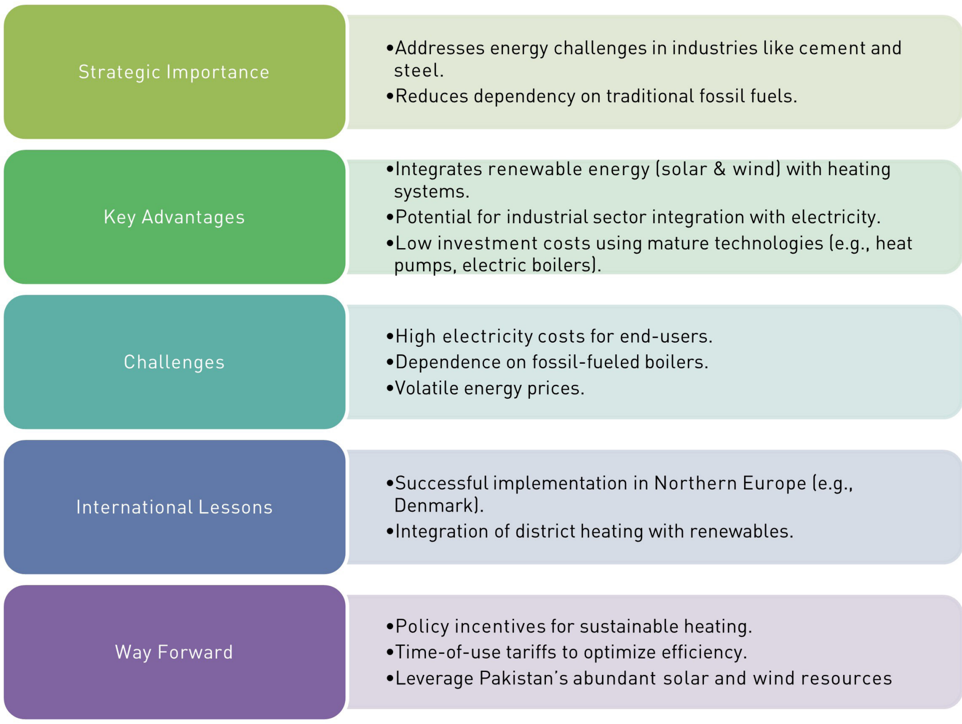


Figure 14: Power-to-Heat (P2H): A Strategic Solution for Pakistan

Box 5 | Case Study V: Exploring Hydrogen: Unlocking Pakistan's Clean Energy Potential

Recently, National Energy Efficiency and Conservation Authority (NEECA) organized an event to launch their study on clean hydrogen in Pakistan. In Pakistan, the strategic development of renewable hydrogen value chains is set to significantly impact the nation's energy paradigm. Projects ranging from large hydro dams in the north to solar and wind power applications are tailored to reduce reliance on imported fuels and decarbonize both transport and industry. Notably, these initiatives offer additional benefits such as emissions reductions in heavily polluted areas and leverage existing gas pipeline infrastructure. Suitability for pilot projects is high in urban centers where hydrogen mobility can address transportation-related pollution. On a longer timescale, the attractiveness of these projects remains high due to their potential to contribute to energy security, economic development, and environmental sustainability. The integration of renewable hydrogen into Pakistan's energy system represents a forward-thinking approach to tackling the 3Es crisis, fostering a greener economy, and ensuring secure and sustainable energy for future generations. Out of 13 potential projects including hydrogen value chain based on hydro, solar, bagasse, wind, from national grid to off grid and micro hydro, 6 are highly attractive in terms of 10 to 15 years' time scale. The Quaid e Azam solar park for stable hydrogen is also one of the economically suitable project.

#	Project	Location	Fit with Top 3 Energy Priorities	Additional Benefits	Suitability for Pilot (2-3 years)	Attractiveness (10-15 years)
1	Large hydro dam to produce H2 for transport in multiple cities in north	Mangla Dam, Azad Kashmir & northern cities	Reduced crude oil imports	Emissions reduction in heavily major northern cities, decarbonisation of transportation	High (if use only one city for H2 mobility)	High
2	Small-scale hydro power close to city to produce H2 for mobility	Deg Outfall dam, Lahore, Punjab	Reduced crude oil imports	Emissions reduction in heavily polluted urban metropolis, decarbonisation of transportation	High (Deg is small, but can replicate)	High
3	Use hydro power to produce hydrogen for gas grid admixing	Any hydro scheme close to a gas pipeline	Reduced LNG imports	Decarbonisation of energy, leverage gas pipeline grid	High	High
4	Mega-dam hydro power for H2 pipeline to Lahore	Tarbela/ Mangla dams and pipeline to Lahore	Reduced LNG demand in major cities in the north of Pakistan	Decarbonisation of industry, transportation, and domestic applications, leverage gas pipeline grid	Low (must be a large project)	High
5	Mega-dam hydro power for H2 and salt caverns storage	Tarbela/ Mangla dams and Chakwal, Punjab	Better energy supply/demand balance through each year: summer to winter, reduced LNG imports	Decarbonisation of winter heating and power production, leverage gas pipeline grid	Low (must be a large project)	High
6	H2 from solar power at Quaid-e-Azam for stable H2 production	Bahawalpur, Punjab	Reduces imported LNG & crude demand	H2 mobility on north/south route, decarbonise transportation, leverage gas pipeline grid	High	High
7	H2 from solar power at Bahawalpur for daily power balance	Bahawalpur, Punjab	Better energy supply/demand balance through each day: midday to evening	H2 mobility on north/south route, decarbonise transportation	High	High
8	Bagasse-fired power to H2 for ammonia production	Daharki, Sindh	Reduces imported LNG demand	Decarbonisation of industry & agriculture	Medium (small scale, low utilization)	Medium
9	Solar power to H2 for remote areas (e.g., mining vehicles or rural villages)	Thar, Sindh	Reduces imported crude demand	Emissions reduction in remote areas, decarbonisation of industry	High	Medium (small, limited benefits)
10	Wind power for H2 to local use and LH2 import/export terminal	Jhimpir/ Karachi, Sindh	Reduces imported LNG demand, better energy supply/demand balance	Enables LH2 exports, decarbonisation of energy, leverage gas pipeline grid & gas power plants	Medium (complex, mid-scale project)	Medium
11	Off-peak surplus power from the Orange Line Metro system for H2	Lahore, Punjab	Reduces imported crude demand, reduces imported LNG demand	Emissions reduction in heavily polluted urban metropolis, decarbonisation of transportation & heat	Medium (multiple small schemes)	Medium
12	Off-peak surplus heat and power from a potential geothermal plant	Karachi, Sindh	Reduces imported crude demand, reduces imported LNG demand	Emissions reduction in heavily polluted urban metropolis, decarbonisation of transportation & heat	Low (geothermal plants do not yet exist)	Medium
13	Micro-hydro power for micro-grids in northern Pakistan	Naltar Valley, Gilgit Baltistan	Security of power supply through the year, reduced LPG demand (current alternative), affordable energy for a low-income region	Carbon-neutral, pollution-free energy in the north	High (good fit with H2, high social and economic impact)	High

Carbon Markets

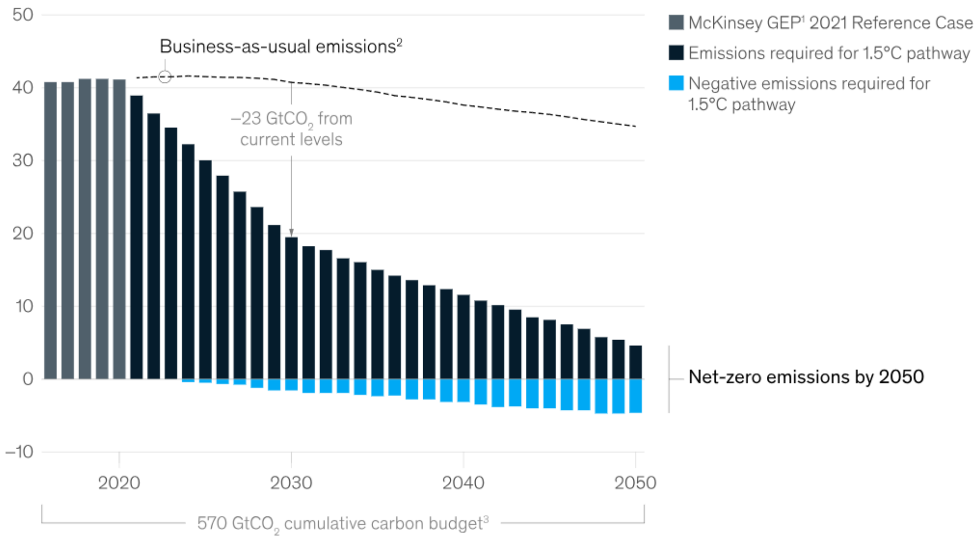
The concept of carbon markets has gained prominence as a viable solution to the global environmental crisis and as a means to build an economic engine in line with sustainability practices. By enabling the trading of carbon credits and offsets, these markets not only address environmental challenges but also open new avenues for economic opportunities, particularly for developing countries like Pakistan, where capital is expensive and financial bottlenecks are major impediments in the development of RE (Stephan and Paterson 2012). Hence, the discussion on carbon markets and their linkages with RE becomes particularly pertinent for Pakistan, a nation grappling with a complex interplay of economic, energy, and environmental crises (3Es).

Carbon markets function by commodifying carbon emissions, allowing businesses to buy and sell carbon credits and offsets. Carbon credit permits the emission of a tonne of CO2, while an offset represents the reduction or removal of a ton of CO2 from the atmosphere. The Kyoto Protocol and Paris Agreement have been pivotal in shaping these markets, yet recent trends indicate a growing interest in regional markets and voluntary carbon trading (Stephan and Paterson 2012).

Integrating carbon markets could be transformative for Pakistan, offering economic incentives for reducing emissions and promoting RE initiatives. RE projects, such as solar and wind power, play a vital role in carbon offsetting. By investing in these projects, Pakistan not only reduces its carbon footprint but also moves towards energy self-sufficiency, addressing its energy crisis (Verra 2024).

However, there are challenges in aligning Pakistan's RE projects with existing carbon market standards. Currently, major carbon standards such as Verra and Gold Standard only allow RE projects to generate carbon credits if the share of renewables in the total electricity generation system is less than 5%. This limitation has posed a hindrance to Pakistan's ambitions of utilizing carbon credits to support its RE initiatives (Verra 2024).

Proceedings of COP28 have attempted to address this issue by introducing the concept of transition credits and coal retirement credits. These credits aim to incentivize the transition from coal-based energy generation to RES. This new approach could potentially open doors for Pakistan to participate more actively in carbon markets, given its ongoing efforts to increase the share of renewables in its energy mix.



Global Energy Perspective.
[2]While emissions fell by a quarter at the peak of COVID-19-related lockdowns, daily emissions have rebounded to be only 5% lower than 2019 levels. Scenarios to 2050 remain the same. Forster et al., "Current and future global climate impacts resulting from COVID-19," *Nature Climate Change*, August 7, 2020, nature.com.
[3]Budget of 570 $GtCO_2$ emissions from 2018 onward offers a 66% chance of limiting global warming to 1.5°C, when assessing historical temperature increases from a blend of air and sea-surface temperatures.
Source: Corinne Le Quéré et al., "Global Carbon Budget 2018," *Earth Systems Science Data*, 2018, Volume 10, Number 4, pp. 2141–94, doi.org; IPCC; *McKinsey Global Energy Perspective 2021*; McKinsey analysis

Figure 15: Global Potential for Carbon Markets by 2050

According to McKinsey (2024), carbon markets present substantial potential for bridging the gap between business-as-usual emissions and the Net-Zero Emissions 2050 target. Integrating RE credits into carbon markets is emerging as a key trend for developing countries, including Pakistan.

While existing market standards pose challenges, the introduction of mechanisms like transition credits and coal retirement credits at COP28 highlights a shifting landscape that could benefit the country. By aligning its RE goals with evolving carbon market mechanisms, Pakistan can address environmental concerns, enhance energy security, and unlock economic opportunities. Continued adaptation to these emerging trends will be crucial to leveraging the full potential of carbon markets for a sustainable future (The Guardian 2023).

Box 6 | Case Study 6: Blue Carbon Credits: Tapping into Pakistan's Coastal Ecosystem Potential

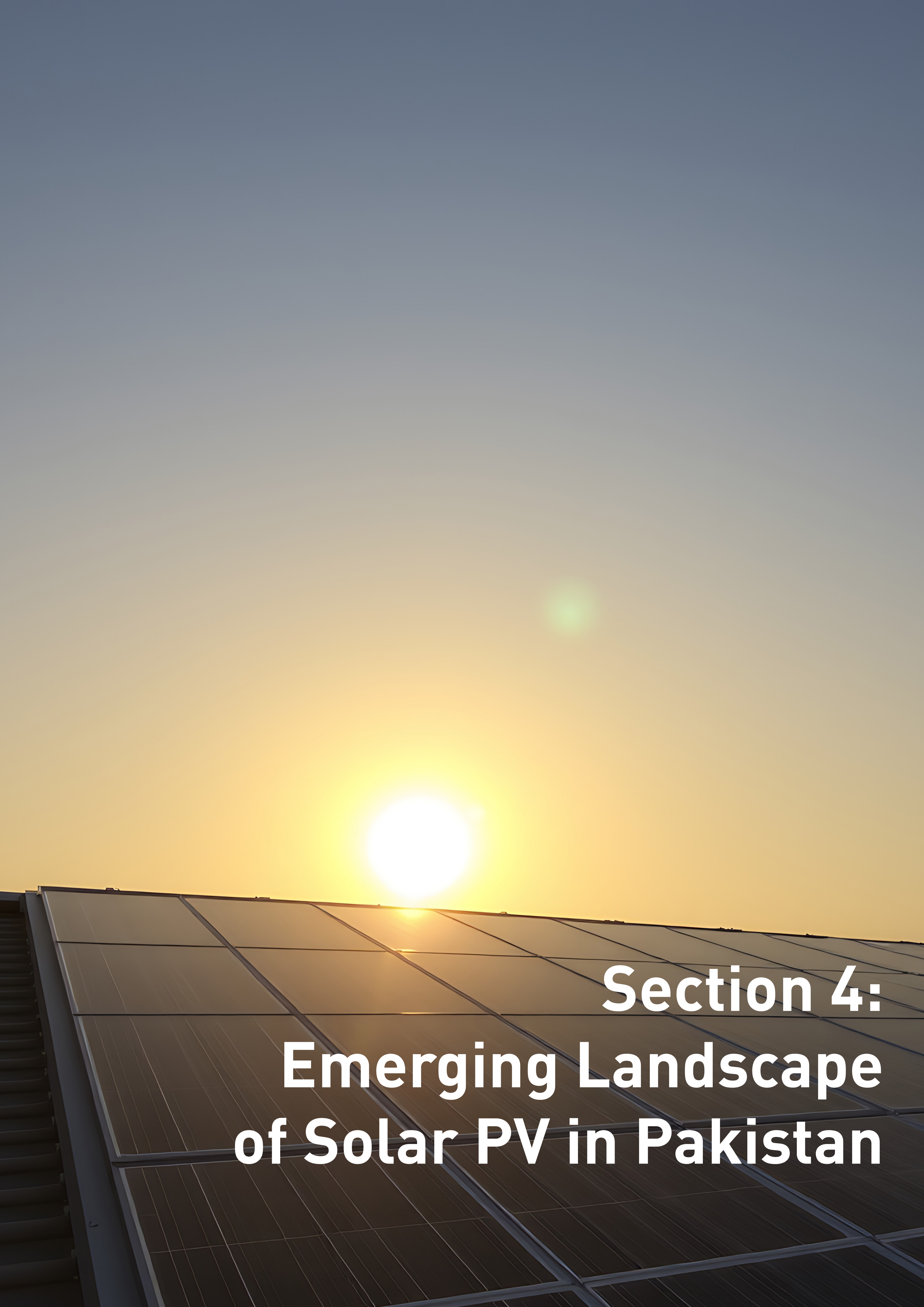
Pakistan's Delta Blue Carbon (DBC) projects have emerged as one of the world's largest mangrove restoration initiatives, showcasing the country's commitment to leveraging blue carbon credits for sustainable development. The DBC-1 project, initiated in 2015, successfully restored 250,000 hectares of mangroves along the Indus Delta. Building on this, the DBC-2 project launched in 2023 aims to expand mangrove restoration efforts to an additional 200,000 hectares, bringing the total target area to 450,000 hectares by 2030. The financial impact of these projects is substantial. By August 2023, Pakistan had already generated USD 40 million in carbon credit sales from the DBC-1 project. With the DBC-2 initiative in place, the Sindh Forest Department has set an ambitious target of earning USD 12 billion through Certified Emission Reductions (CERs) by 2075.

Moreover, the carbon credits from these projects have received high demand on international platforms. In June 2023, an auction for credits from the Delta Blue Carbon project was oversubscribed, with credits selling at approximately USD 29.72 per tonne. This price is significantly higher than average global rates, indicating the project's credibility and the premium placed on nature-based solutions like mangrove restoration.

Success of the DBC projects not only underscores Pakistan's growing presence in the blue carbon market but also shows its strategic integration with the country's RE development. The DBC initiatives have already generated over **USD 40 million in carbon credits**, which Pakistan is directing toward enhancing its RE infrastructure, specifically targeting the coastal areas where wind and solar potential is high. By reinvesting these funds, the government aims to support the installation of an additional 100 MW of wind power and **50 MW of solar energy along the Sindh coastline by 2030.**

Furthermore, the expansion of mangrove restoration in these regions provides natural protection for renewable energy installations, such as wind farms and solar arrays, against coastal erosion and extreme weather events, reducing infrastructure vulnerability. The dual approach of carbon sequestration through mangrove restoration and reinvestment into renewable energy projects is expected to reduce emissions by over 5 million tonnes of CO2 annually by 2030, aligning with Pakistan's commitment to increase its renewable energy share to 30% of its total energy mix under the ARE Policy, 2019.

Integration of sector coupling technologies, including P2X applications like P2G, hydrogen production, and Power-to-Heat, alongside innovative mechanisms such as Peer-to-Peer (P2P) energy trading and carbon markets, highlights Pakistan's potential to transition toward a sustainable, low-carbon energy system. By aligning these technologies with RE goals, the country can enhance energy security, reduce emissions, and foster economic growth. However, realizing this potential requires addressing scalability, investment frameworks, and policy alignment while ensuring technology adoption is supported by robust infrastructure and financial incentives.



Section 4: Emerging Landscape of Solar PV in Pakistan

SECTION 4: Emerging Landscape of Solar PV in Pakistan

Background

Over recent years, Pakistan has witnessed a considerable shift towards RE, with solar photovoltaic (PV) adoption emerging as a prominent driver of this change. Despite its potential, solar PV growth in Pakistan is substantially underreported, mainly due to its decentralized nature. Official records from the Alternative Energy Development Board (AEDB) cite Pakistan's installed solar PV capacity at approximately 1,244 MW as of 2023. However, satellite imagery and sector-specific studies suggest that actual capacity is far higher, especially considering the surge in rooftop and off-grid installations, which remains unaccounted for in official data (BloombergNEF 2024; IEEFA 2024).

To illustrate, according to reports, rooftop solar capacity nearly doubled between 2022 and 2023, with an additional 764 MW added through net-metered systems (BloombergNEF 2024). This underreported growth (refer to Table 13) represents a gap in the national energy tracking system, reflecting the need for formal mechanisms to accurately capture decentralized solar installations across urban and rural areas. For context, Table 14 shows the reported and estimated unrecorded solar PV capacities from 2021 to 2023:

Table 13: Comparison of Reported and Estimated Solar PV Capacity in Pakistan (2021-2023)

Year	Official Solar PV Capacity (MW)	Estimated Unrecorded Capacity (MW)	Total Estimated Capacity (MW)
2021	1,010	300	1,310
2022	1,244	500	1,744
2023	1,568	764	2,332

Source: Mordor Intelligence 2024.

This gap not only reflects an emerging but largely invisible solar market but also highlights a strategic challenge for Pakistan's energy planning. Solar energy has gained popularity in recent years due to favorable conditions, with irradiation levels ranging between 4.5 and 6.5 kWh per square meter daily and over 300 sunny days annually. These conditions make solar a promising solution for addressing Pakistan's chronic energy shortages, which contribute to a national energy deficit of around 5,000 MW. High solar potential is particularly evident in regions like Sindh, Balochistan, and southern Punjab, which enjoy the highest solar radiation levels in the country (The Express Tribune 2024; Power Technology 2024).

Solar PV installations have been further bolstered by a favorable import market. Pakistan's imports of solar technology have surged, reflecting both residential demand and large-scale project requirements. By 2023, solar equipment imports, valued at approximately USD 1.11 billion, translated to around 4 GW of module capacity, fueling residential and commercial solar installations alike (AsiaOne 2024).

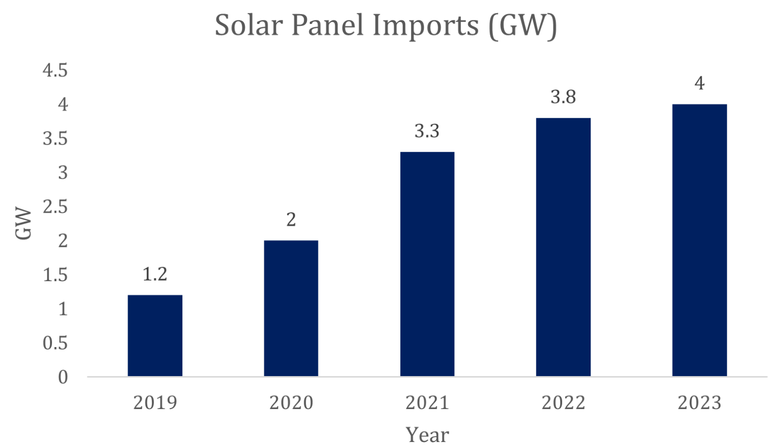


Figure 16: Solar Panel Imports in Pakistan (2019-2023)

Additionally, solar PV is critical for achieving Pakistan's climate targets under its Nationally Determined Contributions (NDCs). The country aims to reduce its greenhouse gas emissions by 50% by 2030, conditional on international support. Solar PV is expected to play a significant role in achieving this reduction, alongside wind and hydropower (Ministry of Climate Change 2021).

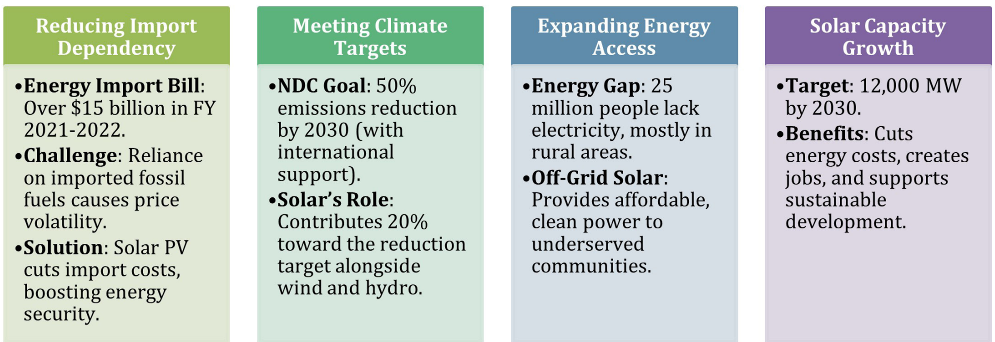


Figure 17: Solar PV in Pakistan: Cost, Targets, Access & Growth

Pakistan primarily sources its solar panels from major exporters, including China, the United States, and South Korea. From January 2022 to December 2023, Pakistan imported 8,355 shipments of solar panels, marking a 77% increase compared to the previous 12 months (Volza 2024). In December 2023 alone, the country imported 717 shipments, showing a 156% year-on-year increase from December 2022, and a 20% increase from the previous month of November 2023. This significant rise highlights the growing demand for solar technology. Interestingly, globally, Pakistan ranks as the third-largest importer of solar panels, following Vietnam and the United States, with 24,003 shipments.

Between 2016 and 2023, solar energy witnessed significant growth in Pakistan, as reflected in the increase in installed solar capacity from 207 MW in 2016 to 1,240 MW in 2023 (Global Energy Monitor 2024). However, the expansion rate has fluctuated, with notable spurts during certain periods (e.g., 2017-2018 and 2020-2021), likely influenced by various internal and external factors, such as government policies, investment climates, and energy demand (Finance Division 2024).

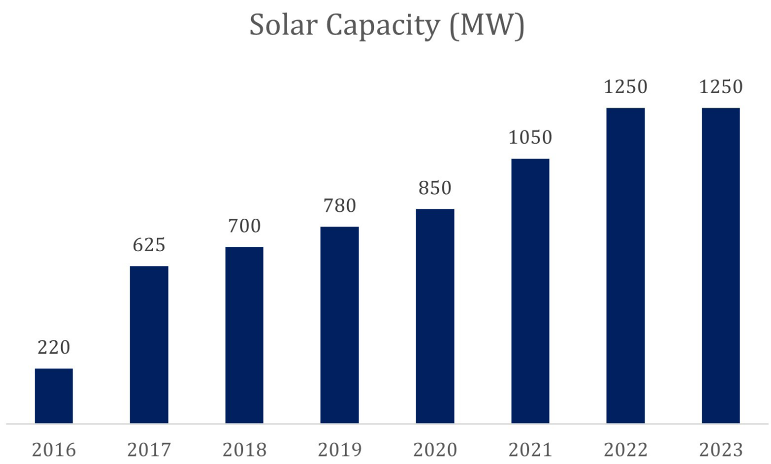


Figure 18: Solar PV Uptake

Box 7 | Case Study 7: Solar PV vs. Fossil Fuels: A Cost-Effective Energy Solution for Pakistan

At an average cost of USD 0.06 per kWh, solar PV is nearly 50% cheaper than LNG-based power generation and considerably less expensive than coal. By shifting to solar, Pakistan can reduce its dependency on imported fuels, helping to stabilize energy prices and improve economic resilience. Solar PV also produces zero emissions during operation, supporting Pakistan's climate goals by reducing greenhouse gas emissions in the power sector.

Energy Source	Cost per kWh (USD)
Solar PV	0.06
LNG	0.12
Coal	0.10

Solar PV Costs

A major factor contributing to Pakistan's solar PV growth is the significant cost reduction in solar technology over the past decade. Globally, solar PV costs have dropped by nearly 80%, making it one of the most cost-effective energy sources at approximately USD 0.06 per kWh. This affordability has driven widespread adoption across various income groups, particularly among middle-income households and small businesses seeking alternatives to the expensive and unreliable national grid (BloombergNEF 2024; IRENA 2022).However, this decentralized uptake of solar PV, particularly in the form of rooftop systems, has largely occurred outside formal regulatory channels, resulting in an unregulated solar market.

Regional Analysis

South Asia's EE landscape has rapidly expanded, driven by national targets, decreasing technology costs, and rising demand for sustainable energy. India leads South Asia's solar capacity, with over 66 GW installed by the end of 2023, supported by ambitious government targets and incentives that aim to achieve 280 GW of solar by 2030. In contrast, Bangladesh has a smaller installed capacity at around 900 MW, yet it has prioritized rooftop solar for off-grid rural electrification, making it a notable example of decentralized solar application. Although Pakistan's unregistered solar PV capacity stood at approx. 2,332 MW in 2023, the country lags behind regional counterparts like India in solar PV deployment, mainly due to regulatory, financial, and infrastructural barriers (IRENA 2024; World Economic Forum 2024).

Table 14: Solar PV Capacity in South Asia (2023) and 2030 Targets		
Country	Solar PV Capacity (MW)	2030 Target (MW)
Pakistan	1,244 (2,332 estimated)	7,500
Bangladesh	900	4,100
Sri Lanka	630	1,500
Nepal	200	600

Cost reductions in solar technology have further accelerated adoption across the region. By 2023, the levelized cost of electricity (LCOE) for solar PV reached around USD 0.04 per kWh in India, driven by large-scale auctions and economies of scale, compared to approximately USD 0.06 per kWh in Pakistan. This cost difference highlights the advantages of competitive bidding and streamlined regulatory frameworks seen in India's solar sector (World Bank 2024; IRENA 2024).

In terms of policy, India's favorable net metering, tax incentives, and subsidized loans have enabled significant growth in both utility-scale and rooftop solar PV. Pakistan's net metering policy has facilitated rooftop solar adoption primarily in urban areas, contributing over 764 MW by 2023, yet regulatory gaps and infrastructure challenges have limited broader impact. Bangladesh has also employed supportive policies focused on rural electrification through solar home systems (SHS), achieving around 6 million SHS installations in off-grid areas as of 2023 (GIZ 2024).

The regional comparison highlights that Pakistan's solar PV sector has potential for rapid growth if regulatory improvements are implemented. Learning from India's model, where solar auctions and competitive bidding have reduced costs and improved project viability, Pakistan could leverage similar frameworks to stimulate both large-scale and decentralized solar deployment. Additionally, increasing incentives for rooftop installations and simplifying licensing processes could further support Pakistan's ambitions to achieve a 30% RE share by 2030 (GIZ 2024).

Regulatory Framework and Policy Developments

In recent years, Pakistan has sought to accelerate its solar PV adoption through a series of regulatory initiatives. NEPRA initially supported this transition by launching the net metering policy in 2015, allowing consumers with distributed solar systems to sell excess electricity back to the grid. This policy quickly encouraged widespread rooftop solar adoption, with around 2.2 GW of net-metered capacity installed by 2024, primarily in urban regions. However, as adoption rates soared, financial strain on distribution companies (DISCOs) and grid management challenges prompted policy reviews, resulting in recent regulatory shifts aimed at balancing solar growth with grid stability and economic sustainability (IEEFA 2024; GlobalData 2024).

Table 15: Pakistan's Solar PV Regulatory Issues		
Regulatory Component	Details	Expected Impact
Gross Metering Transition	All solar energy fed into the grid	Reduces financial burden on DISCOs
Reduced Buyback Rates	Buyback rate reduced from PKR 27 to PKR 15	Extends payback periods, reduces returns
System Size Cap	Capped at 80% of sanctioned load	Prevents grid overloads, promotes storage
AREP 2019 Incentives	Tax exemptions, direct sales, auction systems	Encourages large-scale commercial projects

Section 5: Challenges, Recommendations and Conclusion

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Pakistan's RE sector faces several interconnected challenges that hinder its progress toward a sustainable and low-carbon future. Addressing these obstacles requires coordinated action from policymakers, regulatory bodies, and industry stakeholders. Some of the key challenges pertaining to integration of RE are given below along with recommendations and key actions for relevant stakeholders over the short- (1 year), medium- (2-5 years) and long-term (5-10 years).

Inconsistent Implementation of Renewable Energy Policies

Pakistan's RE landscape is shaped by a series of strategic policy documents, including the Integrated Generation Capacity Expansion Plan (IGCEP) 2024, the Alternative Renewable Energy (ARE) Policy, 2019, the National Electricity Plan 2023-27, and the Fast Track Solar PV Initiatives 2022. These policies set ambitious goals for transitioning the country towards a more sustainable energy mix. However, despite these comprehensive frameworks, the implementation of these policies has been inconsistent, leading to several critical challenges that need to be addressed urgently. This section delves deeper into the specific issues arising from this inconsistency and offers detailed recommendations to mitigate these challenges.

Issue 1: Policy and Regulatory Alignment

The lack of coordination between federal and provincial authorities creates fragmented policies, delays in project approvals, and inefficiencies in energy planning. This misalignment undermines investor confidence and slows RE adoption.

Issue 2: Financing and Investment Barriers

Limited access to concessional financing and high capital costs deters private sector participation in RE. Smaller developers face significant difficulties securing credit due to stringent lending requirements and perceived risks.

Issue 3: Inefficiencies and Lack of Transparency in the Competitive Bidding Process

The renewable energy bidding process in Pakistan faces significant challenges, undermining its potential to attract credible investments. Issues such as poorly defined bidding criteria, lack of standardization, and opaque evaluation mechanisms have created inefficiencies. These shortcomings often result in less qualified bidders securing contracts due to inadequate oversight or political interference.

Issue 4: Technical and Human Resource Capacity

Inadequate technical expertise and insufficient training programs for key stakeholders, including developers, policymakers, and regulators, hinder the effective implementation of RE projects.

Issue 5: Institutional Inefficiencies

Overlapping mandates among key institutions such as the Ministry of Energy, NEPRA, and AEDB create inefficiencies and duplication of efforts. These issues delay project implementation and reduce overall system effectiveness.

Recommendations

- Establish a **centralized policy coordination body** to harmonize federal and provincial frameworks, streamline approval processes, and develop standardized bidding and licensing systems. A **single-window clearance system** should also be introduced to reduce bureaucratic delays and foster transparency in RE projects.

- Develop **concessional finance mechanisms** such as green bonds, credit guarantees, and impact investment funds to attract private capital. Strengthen PPPs and incentivize local manufacturing of RE components to lower costs and build a sustainable supply chain.

- Develop a **standardized bidding framework** overseen by an independent regulatory body, with clear guidelines and a digital platform to enhance transparency, attract high-quality investors, and reduce project costs.

- Invest in **smart grid technologies** and advanced metering infrastructure to manage intermittent VRE sources. Expand transmission capacity in high-potential regions and deploy **Battery Energy Storage Systems (BESS)** to improve grid reliability and flexibility.

- Define clear roles and responsibilities for each institution and foster inter-agency collaboration. Strengthen the role of NEPRA in enforcing regulatory compliance and AEDB in promoting RE projects.

Timeline	Relevant Actor/ Stakeholder	Responsibility
Short-Term (1-2 Years)	MoE	Ensure consistent implementation of national RE policies across provinces by developing and enforcing a centralized policy monitoring framework. This will standardize the application of the ARE Policy 2019 and IGCEP 2024 nationwide
	NEPRA	Improve transparency and efficiency in RE project procurement by issuing standardized guidelines and evaluation criteria for competitive bidding. This will streamline the bidding process by Q2 2024.
Medium-Term (3-5 Years)	MoE	Upgrade national grid infrastructure to support increased RE capacity. This includes launching a grid modernization program focused on areas with high RE potential and completing feasibility studies and infrastructure investments by Q4 2025.
	Provincial Energy Departments	Align provincial energy policies with national RE goals by conducting coordinated workshops and policy revisions, ensuring policy alignment by Q3 2025.
Long-Term (5-10 Years)	MoE & AEDB	Establish a local manufacturing base for renewable energy technologies by providing incentives for domestic production of solar panels, wind turbines, and storage systems. The goal is to achieve a robust local manufacturing industry by 2030.
	Ministry of Industry & Production	Develop technical skills within the workforce to support the renewable energy sector by creating vocational training programs focused on RE technologies. This aims to build a skilled workforce ready for deployment by 2028.

Financing Challenges

Unlocking private sector investment remains a cornerstone for scaling up RE projects in Pakistan. Although the costs associated with RE are declining, making them increasingly competitive with fossil fuels, significant challenges persist. Addressing these challenges is crucial for fostering a robust and sustainable RE sector. Below is a detailed analysis of the key financing challenges currently faced by the sector, along with specific and actionable recommendations.

Issue 1: Limited Access to Financing

Small and medium RE developers face significant barriers in accessing financing due to stringent collateral requirements and high-risk aversion among financial institutions. These challenges disproportionately affect newer players lacking financial histories, limiting market competition and growth.

Issue 2: Low Tariffs and Rising Costs

NEPRA's low benchmark tariffs for renewable projects fail to account for rising costs, inflation, and currency devaluation. The benchmark tariff for wind energy, at PKR 4.28/kWh, falls short of covering rising costs driven by inflation, currency devaluation, and increased expenses for imported components and services. Developers also contend with prolonged delays in circular debt payments and foreign exchange risks linked to Operations and Maintenance (O&M) contracts, further straining their finances. These narrow profit margins discourage investment, especially for smaller developers, and constrain the scalability of RE projects in the country.

Issue 3: Complex Land Acquisition and ROW Processes

Developers encounter significant delays in land acquisition due to unclear land titles, inconsistent provincial laws, absence of a centralized land registry and well-defined land tenure rights. These inefficiencies drive up project costs and make land assets less bankable.

Issue 4. Outdated Technical Feasibility Studies

Government-provided feasibility studies often fail to reflect current grid infrastructure and technological advancements, increasing costs and risks for developers who must conduct additional assessments. Additionally, grid integration studies lack the comprehensiveness required to provide confidence to developers, increasing project risks, hindering financing efforts, and causing delays in execution.

Recommendations		
• Introduce concessional financing mechanisms, such as **first-loss guarantees** and **green bonds**, through institutions like InfraZamin and PCGC. These tools should be designed to reduce perceived risks and encourage small developers to enter the market. • **Revise NEPRA tariffs** for solar and wind projects to reflect inflation and rising costs, incorporating mechanisms for periodic adjustments to ensure investor confidence.to reflect actual market dynamics, including inflation adjustments and foreign exchange risks. • Establish a **centralized digital registry** and a **single-window approval system** for land acquisition and ROW clearances. This system should streamline processes across provinces and reduce bureaucratic delays. • Collaborate with **international technical experts** to update feasibility studies **using advanced methodologies.** Accurate and timely studies will provide developers with reliable data, improving project viability. Introduce **phased implementation of policy changes** and **strengthen legal frameworks** for contract enforcement and dispute resolution to build investor trust.		
Timelines	Relevant Actor/ Stakeholder	Responsibility
Short-Term (1-2 Years)	MoF & FIs	Expand concessional financing options by introducing structured finance products, such as first-loss guarantees. These products should target small and medium RE developers to improve access to capital and reduce financial risks, enabling more developers to initiate renewable projects.
	MoE & NEPRA	Adjust tariffs to align with current market dynamics. This includes revising benchmark tariffs for solar and wind energy projects and integrating inflation adjustments to reflect real costs. Such revisions will enhance the financial viability of RE projects, ensuring fair returns for investors and improving investment attractiveness.
Medium-Term (3-5 Years)	MoE & Provincial Governments	Simplify land acquisition and Right-of-Way (ROW) processes. Establishing a centralized land registry system and a single-window approval process will reduce project delays, streamline legal procedures, and improve the bankability of RE projects.
	MoE & International Technical Partners	Work closely with international technical partners to elevate the quality of technical feasibility studies. Through collaboration with experts, the aim is to standardize interconnection studies and adopt advanced methodologies, providing developers with reliable, up-to-date data that reduces project risk and builds investor confidence.
Long-Term (5-10 Years)	MoE, MoF, & Regulatory Bodies	Focus on strengthening regulatory frameworks to support investor protections. Phased regulatory adjustments will allow market participants to adapt gradually, creating a stable and predictable environment that encourages sustained RE investments.
	MoE & Private Sector	Develop PPPs that encourage innovation and investment in RE infrastructure. These PPPs will foster long-term private sector engagement, promote risk-sharing, and create an innovative-driven ecosystem for RE growth.

Grid Integration and Infrastructure Deficiencies

Grid integration is a critical factor in the success of RE projects. The ability to efficiently transmit and distribute electricity from renewable sources like wind, solar, and hydropower is fundamental to achieving Pakistan's energy goals. However, the current state of grid infrastructure poses significant challenges, limiting the potential of RE. Below is a comprehensive analysis of the key issues related to grid integration and infrastructure, followed by detailed recommendations to address these challenges.

Issue 1. Outdated and Inadequate Grid Infrastructure

Pakistan's grid infrastructure, originally designed for centralized fossil fuel-based generation, is struggling to meet the demands of modern RE systems. Aging transmission lines and substations are incapable of managing the variability of solar and wind energy, leading to frequent voltage fluctuations, blackouts, and substantial energy losses during transmission. Furthermore, the absence of advanced technologies such as smart transformers, automated control centers and real-time monitoring systems hampers the seamless integration of RES, causing underutilization of clean energy potential.

Issue 2: Insufficient Transmission Capacity in Renewable Energy-Rich Regions

Pakistan's RE resources are geographically concentrated, with wind corridors in Sindh and solar-rich zones in Balochistan. However, the transmission infrastructure in these areas is inadequate to transfer large volumes of generated electricity to key demand centers like Karachi, Lahore, and Islamabad. Existing transmission lines are often overloaded and unable to support additional capacity, creating significant bottlenecks. These constraints lead to underutilization of RE projects, as many cannot connect to the grid or must operate below capacity. This not only delays financial returns for developers but also impedes the expansion of the sector. The insufficient transmission capacity increases reliance on fossil fuel-based power plants, undermining efforts to reduce carbon emissions.

Issue 3: Lack of Investment in Grid Modernization

Despite the increasing importance of RE, Pakistan's grid modernization has suffered from chronic underinvestment. Government budget constraints have prioritized immediate power generation needs over long-term grid enhancements, while private investors remain reluctant due to regulatory uncertainties and the high risks associated with such projects. The current tariff structures and frameworks fail to provide adequate incentives, further stalling essential grid upgrades. This lack of investment perpetuates inefficiencies, making it difficult to integrate new renewable projects, leading to higher energy losses and costs for consumers. The outdated infrastructure also leaves the power system vulnerable to disruptions and failures, posing significant economic and social risks.

Issue 4. Ineffective Grid Management Practices

Current grid management practices fall short of addressing the complexities posed by RE integration. Deficiencies include a lack of real-time data monitoring, inadequate forecasting tools for renewable generation, and minimal deployment of advanced technologies like smart grids, energy storage systems, and automated demand response. These gaps result in reliance on outdated or inaccurate data for load balancing and energy dispatch decisions, while poor forecasting further hampers efficient grid operations. The absence of effective management tools exacerbates RE curtailment and increases dependence on fossil fuels to stabilize the grid. This inefficiency not only inflates electricity costs but also diminishes the environmental benefits of renewables. Additionally, it contributes to frequent outages and voltage instability, eroding the reliability of the power system and public confidence in RE solutions.

Recommendations

- The MoE and NTDC **should prioritize grid modernization.** This includes replacing outdated components, deploying advanced technologies like smart grids and automated control systems, and investing in infrastructure improvements in RE-rich areas to enhance system reliability and efficiency.

- **Expand transmission capacity** in RE-rich regions by constructing high-voltage lines and enhancing existing infrastructure to handle additional loads. Fast-track approval processes for transmission projects and ensure sufficient budget allocation for these upgrades. Create policies to integrate rooftop solar and community-based wind projects into the grid, offering incentives and standardized processes to maximize localized energy solutions.

- The MoE and NTDC must allocate funds and **seek international financing** for grid upgrades. Improving regulatory frameworks to attract private sector investments through long-term PPAs or PPP models can accelerate modernization efforts. There is need to fast-track transmission projects by establishing streamlined approval mechanisms through a one-stop shop for permits and dedicated funding, such as a **transmission development fund**, to minimize curtailment and optimize RE usage. NEPRA should implement grid access rules prioritizing renewables and support DER integration with clear interconnection procedures and incentives

- Deploy **advanced grid management systems,** including smart grids, energy storage technologies, and real-time monitoring tools. Implement training programs for operators to enhance technical capacity and optimize grid operations for RE integration.

Timeline	Relevant Actor/ Stakeholder	Responsibility
Short-Term (1-2 Years)	MoE & NTDC	Prioritize grid modernization to support RE integration by replacing outdated components like transformers and substations, especially in areas with high renewable penetration. This will enhance grid stability and maximize the use of RE.
	MoE & NTDC	Expand transmission capacity in renewable-rich regions like Sindh and Balochistan to ensure efficient power delivery to demand centers. Immediate projects should be launched to improve transmission lines, reducing congestion and allowing RE to reach major load centers effectively.
Medium-Term (3-5 Years)	MoE, NEPRA & NTDC	Deploy advanced grid management technologies, including smart grids, energy storage, and real-time monitoring systems, to increase grid flexibility and stability. These upgrades will help minimize the curtailment of RE, ensuring efficient and reliable integration into the national grid.
	MoE & NEPRA	Strengthen the regulatory framework for accelerating renewable energy grid integration and simplify the approval processes for grid projects and establish grid access priority for renewables. This approach will fast-track infrastructure development and enhance the integration of renewable sources.
Long-Term (5-10 Years)	MoE, NTDC & Private Sector	Invest in comprehensive grid modernization through PPPs to fund large-scale grid upgrades. This collaborative approach will establish a resilient and flexible grid, enabling it to support continuous growth in RE capacity across Pakistan.

Dependence on Imported Renewable Energy Equipment

Pakistan's renewables sector is heavily reliant on imported equipment, which includes solar panels, wind turbines, inverters, and battery storage systems. This dependency creates several challenges, including increased project costs, exposure to global market fluctuations, and missed opportunities for local economic development. Below is a detailed analysis of the key issues, followed by specific, actionable recommendations aimed at reducing this dependency and fostering the growth of a domestic manufacturing industry.

Issue 1: High Costs Due to Import Duties, Tariffs, and Exchange Rate Volatility

RE equipment is subject to various taxes and duties, including customs duties, sales tax, and additional regulatory charges, which inflate the initial capital costs for project developers. Moreover, the depreciation of the Pakistani Rupee, such as the nearly 20% decline in 2022, further exacerbates these costs by increasing the expense of imported equipment priced in foreign currencies like the US dollar and Euro. These factors collectively raise project costs by as much as 25-30%, making RE less competitive compared to conventional energy sources. The increased costs also result in higher electricity prices for consumers, hindering the transition to a sustainable energy mix.

Issue 2: Vulnerability to Global Supply Chain Disruptions

The reliance on imported equipment exposes Pakistan's renewables sector to global supply chain risks. Disruptions in international trade—whether due to geopolitical tensions, pandemics like COVID-19, or natural disasters—can delay the delivery of critical components such as photovoltaic (PV) modules, inverters, and turbines. For instance, during the height of the COVID-19 pandemic in 2020, several renewables' projects in Pakistan faced delays of up to six months due to the unavailability of imported equipment from China and Europe. Supply chain disruptions lead to project delays, which in turn cause cost overruns and missed deadlines. These delays can result in penalties for developers and reduced confidence among investors. Moreover, prolonged disruptions can lead to project cancellations or the scaling back of planned capacity, ultimately slowing down the country's progress towards its RE targets.

Issue 3: Lack of Local Manufacturing Capabilities

Pakistan has limited capacity to manufacture key RE components domestically. While some basic components, like mounting structures for solar panels, are produced locally, the country lacks the technical expertise and industrial base to manufacture more complex components such as PV cells, wind turbine blades, and advanced inverters. This gap is largely due to the absence of high-tech manufacturing infrastructure, insufficient R&D investment, and the lack of a skilled workforce trained in RE technology. The lack of local manufacturing capability perpetuates dependence on imports, making the sector vulnerable to external market dynamics. This reliance on imports inflates project costs, exposes the sector to market fluctuations, and limits job creation and innovation opportunities, hindering Pakistan's potential to lead in such technologies.

Issue 4: Limited Technology Transfer and Lack of Innovation

The importation of RE equipment from abroad often occurs without sufficient transfer of the underlying technologies or know-how. International suppliers typically provide the final product, but the detailed technical knowledge required for manufacturing, customization, and innovation remains with the foreign companies. This lack of technology transfer is exacerbated by weak intellectual property (IP) protections and limited government support for R&D in renewable energy. The limited transfer of technology inhibits the growth of a domestic renewables sector that can adapt and innovate independently. This also leaves the country dependent on foreign technical support for the operation and maintenance of installations, further increasing costs.

Issue 5: Inadequate Policy Support and Regulatory Barriers

Although the government has introduced some incentives for RE, these have not been sufficient to encourage the establishment of a domestic manufacturing base. Policies aimed at promoting local production, such as import substitution or tariff adjustments, are either weakly enforced or lack the necessary support mechanisms to make them effective. Additionally, regulatory barriers, such as complex approval processes, inconsistent policies across provinces, and a lack of coordination between federal and provincial governments, further discourage investment in local manufacturing. The inadequate policy support and regulatory barriers hinder the growth of a local manufacturing industry, keeping Pakistan dependent on imported RE equipment. This not only limits economic development but also undermines the country's long-term energy security.

Recommendations

- Implementing an **import substitution strategy** by introducing mandatory local content requirements for government-supported projects and adjusting tariffs to make domestic equipment competitive will reduce import dependency over time.

- Government-backed renewable projects should prioritize **locally produced equipment** through long-term procurement agreements, reducing dependency on imports and enhancing cost-effectiveness.

- The government should **introduce tax exemptions, rebates, and subsidized loans** for RE equipment manufacturing, focusing on establishing facilities within special economic zones (SEZs) dedicated to the sector. Jointly funded by the government and private sector, **Centers of Excellence** should be established to provide specialized training to engineers and technicians, building the workforce required for advanced manufacturing. Partnerships between local universities and international companies, with government-backed R&D funding, can ensure technology is adapted to local conditions, strengthening domestic production capabilities.

- Encouraging **partnerships between local companies and international firms** will facilitate technology transfer and enable the domestic production of key components like photovoltaic cells and wind turbine blades.

- Strengthen policy frameworks to **promote local manufacturing** by introducing well-enforced incentives such as tax breaks, import duty exemptions on raw materials, and subsidies for RE manufacturing plants. **Simplify regulatory approval processes** and **establish a centralized coordination mechanism** between federal and provincial governments to ensure consistent and supportive policies for domestic production.

Timeline	Relevant Actor/ Stakeholder	Responsibility
Short-Term (1-2 Years)	MoIP & MoE	Incentivize local manufacturing of RE equipment by offering tax exemptions and subsidized loans for setting up manufacturing facilities. This will help reduce reliance on imports and support the establishment of a domestic industry.
	MoIP	Implement import substitution strategies, enforcing local content requirements for renewables projects. This approach will help decrease dependency on imported components, enhancing the resilience of the local industry.
Medium-Term (3-5 Years)	MoIP & Private Sector	Facilitate technology transfer and innovation by establishing joint ventures for local manufacturing of essential components. This strategy will enhance local manufacturing capabilities and drive innovation in the sector.
	MoST & MoE	Support technology development by launching a fund for grants and loans targeting renewables innovation. This fund will foster the local production of advanced RE technologies.
Long-Term (5-10 Years)	MoIP, MoE & Private Sector	Develop comprehensive manufacturing infrastructure by building large-scale facilities in dedicated economic zones. This will establish a self-sustaining RE industry, boosting economic growth and local employment.
	MoIP & MoF	Strengthen policy support for manufacturing by simplifying processes and enhancing access to financing. This supportive environment will encourage investment in local manufacturing, creating a favorable landscape for the industry.

Challenges with Independent Power Producers (IPPs) in Pakistan's Power Sector

In recent past, the relationship between Independent Power Producers (IPPs) and the Government of Pakistan has become increasingly strained, leading to significant challenges in the power sector. The core of the issue lies in disputes over payment obligations, tariff adjustments, and the renegotiation of contracts that were initially agreed upon under less favorable conditions. These disputes have led to a buildup of circular debt, delays in payments to IPPs, and growing mistrust between the government and private power producers. This situation has resulted in a lack of new investments in the power sector, as both local and international investors are wary of entering a market where the financial returns are uncertain and where contracts are subject to renegotiation under pressure. The core of issues lies in disputes over payment obligations, tariff adjustment, and the renegotiation of contracts that were initially agreed upon under less favorable conditions. These disputes have led to build up on the circular debt, delays in payments to IPPs, and growing mistrust between them.

Issue 1: Impact of Circular Debt on Renewable Energy IPPs

The accumulation of circular debt, now exceeding PKR 2.5 trillion, has had a particularly adverse effect on RE IPPs. Circular debt arises from the gap between the cost of electricity production and the revenue generated by power distribution companies (DISCOs), exacerbated by transmission losses, unpaid subsidies, and delays in tariff adjustments. Such IPPs, especially those operating under older contracts, are increasingly finding themselves at the back of the payment queue, with substantial delays in receiving payments for the electricity they generate. This delay undermines the financial viability of such projects, which typically operate under tighter margins compared to conventional energy projects. The resulting cash flow issues hinder these IPPs' ability to service their debts, maintain their operations, and invest in scaling up capacity.

Issue 2: Renegotiation of Power Purchase Agreements (PPAs) and its Impact on Investor Confidence

In an attempt to reduce the financial burden on the state, the government has sought to renegotiate PPAs with IPPs, including those in this sector. These renegotiations often focus on reducing the agreed tariffs or altering other terms of the contracts. While the government views these renegotiations as necessary to manage fiscal pressures, they have had a destabilizing effect on investor confidence. RE projects, which require significant upfront capital investment, rely on the predictability of long-term PPAs to secure financing. The uncertainty caused by the threat of renegotiation or unilateral changes to these agreements discourages both local and international investors from committing to new projects, particularly in the sector, where perceived risks are already high.

Issue 3: Delayed Payments and Financial Strain on Renewable Energy IPPs

Delays in payments from the government to renewables IPPs have become a chronic issue, exacerbating the financial strain on these companies. The delayed payments are a direct result of the circular debt problem and the financial instability of DISCOs. For RE projects, which often operate under tight financial constraints, these delays can lead to significant operational challenges. Without timely payments, IPPs struggle to cover their operational costs, repay loans, and invest in maintenance or expansion. This financial strain can force IPPs to curtail production, reduce workforce, or even consider halting operations altogether, which would severely impact the country's energy supply and its ability to meet RE targets.

Issue 4: Legal and Regulatory Uncertainty Impacting Renewable Energy Investments

The ongoing disputes between IPPs and the government, particularly around the renegotiation of PPAs and the inconsistent application of regulations, have created an environment of legal and regulatory uncertainty. This uncertainty is particularly damaging for the sector, where long-term stability and clear regulatory frameworks are essential for attracting investment. Investors are concerned that the rules governing renewables projects could change without notice, undermining the financial assumptions on which these projects are based. This uncertainty makes it difficult to secure financing, as lenders are hesitant to commit funds to projects that may be subject to future renegotiations or adverse regulatory changes.

Issue 5: Impact on Future Renewable Energy Investments

The combination of circular debt, payment delays, PPA renegotiations, and regulatory uncertainty has significantly eroded investor confidence in Pakistan's RE sector. Both local and international investors are increasingly cautious about committing to new projects, particularly those that require large capital investments and long-term financial commitments. This hesitancy poses a serious threat to Pakistan's ability to meet its RE targets, as the country requires substantial new investments to expand its capacity, modernize the grid, and reduce its dependence on fossil fuels.

Recommendations

- The government should create a **RE payment fund** financed through **green energy bonds** and **electricity tariff revenues.** This fund can prioritize timely payments to RE IPPs, ensuring financial security and mitigating delays caused by circular debt.
- Offering benefits such as prioritization in future approvals, streamlined regulations, or access to **government-backed financing** can encourage IPPs to participate in restructured agreements, fostering a balanced energy ecosystem.
- **Ring-fencing payments for R**E or separate payment mechanism exclusively for renewable IPPs will safeguard investments and encourage further development in the sector, shielding it from broader financial instability in the power sector.
- The government should collaborate with **IPPs on a voluntary program** to extend contract durations or restructure payment schedules in exchange for reduced tariffs, improving financial sustainability without undermining investor confidence.
- Dedicated **escrow accounts** or payment guarantees should be established to ensure IPPs receive payments promptly, even if DISCOs encounter financial difficulties, reducing risks for investors and lenders.

Timeline	Relevant Actor/ Stakeholder	Responsibility
Short-Term (1-2 Years)	Ministry of Energy (Power Division) & Renewable IPPs	Ring-fence payments for RE projects to provide financial security to IPPs. This action will encourage more investment in RE by minimizing payment delays caused by broader power sector financial challenges.
	Ministry of Finance & NEPRA	Collaboratively address financial constraints and circular debt challenges by reassessing and rebalancing existing PPAs with renewable IPPs. Initiate a voluntary rebalancing program that allows IPPs to adjust terms, such as extending contract durations for reduced tariffs, to maintain investor confidence.
	NEPRA & Private Sector Developers	Encourage participation in the rebalancing program. NEPRA could offer incentives to IPPs, including prioritization in future project approvals, streamlined regulatory processes, or access to government-backed financing options.
Medium-Term (3-5 Years)	Ministry of Finance, Ministry of Energy & State Bank of Pakistan (SBP)	Enhance payment security for RE projects by establishing escrow accounts or offering payment guarantees. Allocate funds or guarantees to ensure IPPs receive timely payments, even if DISCOs encounter financial challenges. These security mechanisms reduce the risk of delayed payments, making RE projects more attractive to both investors and lenders.

Long-Term (5-10 Years)	NEPRA	Ensure that regulatory changes are predictable and gradual to avoid disrupting ongoing projects, creating a stable investment environment.
	NEPRA & Ministry of Finance	Enhance legal protections for investors, especially in contract enforcement and dispute resolution.
	Board of Investment (BoI) & Ministry of Energy	Ensure policy stability and support through incentives, such as tax breaks, long-term off-take agreements, and protections against future renegotiations. Establishing a dedicated investment promotion unit within the BoI focused on renewables could further strengthen investor relations by providing clear information, support, and showcasing Pakistan as a competitive market for investments.

Strategic Challenges

Pakistan's RE transition faces significant challenges that jeopardize the attainment of its ambitious energy goals outlined in policies. While these frameworks aim to ensure a cleaner, sustainable energy future, a host of barriers—including policy misalignment, bureaucratic inefficiencies, technological dependency, and economic constraints—continues to impede progress. These challenges are interconnected, stemming from systemic gaps in governance, infrastructure, and investment ecosystems, and their resolution is critical to achieving energy security, economic growth, and climate resilience. By addressing these issues strategically, Pakistan can unlock its vast potential, ensuring a just and equitable energy transition that aligns with global sustainability goals. This section delves into the key challenges that undermine progress and provides actionable pathways to overcome them.

Issue 1: Lack of Integration in Hard-to-Abate Industries

Power-to-Heat (P2H) systems have the potential to revolutionize heating in energy-intensive industries such as cement, steel, and chemicals. However, the adoption of P2H technologies in these hard-to-abate sectors faces significant barriers. The primary challenge is the heavy reliance of these industries on traditional fossil fuels, which are deeply entrenched due to their historical use, availability, and relatively lower short-term costs. The infrastructure and operational processes in these industries are not designed to accommodate RE technologies like P2H, creating a major hurdle for transition. Moreover, these industries often lack the financial incentives or policies needed to transition toward P2H systems. The absence of pilot projects or demonstrable examples of successful integration further exacerbates the hesitation to adopt these technologies. Without a clear roadmap or guidance from the government or industry bodies, these sectors remain hesitant to invest in P2H, despite the long-term environmental and economic benefits.

Issue 2: High Electricity Costs for End Users

The financial viability of P2H systems is significantly undermined by the high cost of electricity in Pakistan. Electricity tariffs in the country are among the highest in the region, driven by inefficiencies in the energy production and distribution system. This makes the operational costs of heat pumps, electric boilers, and other P2H technologies prohibitively expensive for both residential and industrial users. The volatility of electricity prices, compounded by frequent energy crises and load-shedding, further deters potential adopters. For low- and middle-income households, the additional cost burden of switching to P2H is unsustainable. Similarly, small and medium-sized enterprises (SMEs) and industrial units face increased operational expenses, which can affect their competitiveness in local and global markets. Without targeted subsidies or financial mechanisms to reduce costs, the adoption of P2H will remain limited to a few sectors, leaving its potential largely untapped.

Issue 3: Lack of Policy Incentives for Decentralized Heating Solutions

The adoption of decentralized P2H systems, particularly in residential and small-scale industrial settings, faces significant challenges due to the absence of clear policy frameworks. Unlike centralized heating systems, decentralized solutions require tailored regulations and incentives to encourage widespread deployment. In Pakistan, however, there is a lack of targeted policies to promote the use of small-scale P2H technologies. Additionally, the absence of standardization in equipment, installation procedures, and maintenance protocols poses risks for early adopters. Without these safeguards, potential users are concerned about the reliability and efficiency of decentralized P2H systems. The lack of awareness campaigns or government-backed demonstration projects further limits public understanding of the benefits of decentralized heating solutions. Consequently, P2H adoption remains confined to niche markets, failing to achieve the scale necessary for impactful energy transition.

Issue 4: High Initial Costs for Hydrogen Production

Hydrogen production through electrolysis, a key component of Power-to-Gas (P2G) systems, is associated with high capital expenditure (CAPEX) requirements. Electrolyzers, the core technology for hydrogen production, are expensive, with costs ranging from USD 1,000 to USD 1,600 per kWel depending on the technology used. These high costs create significant entry barriers for both public and private sector stakeholders. Additionally, the efficiency of current electrolyzers remains limited, with energy efficiency levels between 50% and 75%. This results in higher operational costs, making hydrogen less competitive compared to fossil fuels. For Pakistan, where financial resources are already stretched thin, the upfront costs and limited efficiency of P2G technologies represent a major challenge. Without substantial subsidies or external funding, the adoption of hydrogen production systems will remain out of reach for most stakeholders.

Issue 5: Lack of Regulatory Framework for Hydrogen Integration

Despite the growing global emphasis on hydrogen as a clean energy source, Pakistan lacks a comprehensive regulatory framework to support its production, storage, and utilization. The absence of standardized safety protocols and infrastructure guidelines creates uncertainty for investors and project developers. For instance, hydrogen storage and transportation require specialized facilities and technologies to ensure safety and efficiency, but no clear national guidelines exist to address these requirements. This regulatory gap also limits the integration of hydrogen into existing energy systems, such as natural gas pipelines. Without clear policies and incentives, stakeholders are hesitant to invest in hydrogen infrastructure. The lack of coordination between federal and provincial governments further complicates the development of a cohesive hydrogen strategy, delaying its adoption and implementation.

Issue 6: Limited Infrastructure for Hydrogen Storage and Distribution

The infrastructure required for large-scale hydrogen storage and distribution is virtually nonexistent in Pakistan. Hydrogen storage involves complex technologies such as pressurized tanks, cryogenic storage, or chemical carriers, all of which require significant investment. Similarly, the transportation of hydrogen demands dedicated pipelines or specialized transport systems, neither of which are currently available in the country. The lack of infrastructure not only increases the cost of hydrogen projects but also limits their scalability. For industries and transportation sectors to adopt hydrogen as a fuel, an extensive storage and distribution network is essential. However, the absence of such infrastructure in Pakistan means that even if hydrogen production increases, its utilization will remain restricted, undermining the potential of P2G technologies.

Recommendations

- Introduce **targeted policy incentives** such as tax rebates, subsidies, and low-interest financing to drive the adoption of Power-to-Heat (P2H) technologies in industrial heating processes. Strengthen these efforts with government-supported pilot projects to showcase the feasibility and benefits of P2H systems. Further, deploy and test P2H technologies in industrial sectors, integrating IoT-enabled sensors and AI for real-time monitoring and optimization to enhance efficiency, scalability, and operational effectiveness.

- Implement **electricity tariff reforms** and targeted subsidies to reduce the costs of RE-based heating technologies, enabling wider adoption by residential, SME, and industrial users transitioning to Power-to-Heat (P2H) systems. Complement these measures by deploying advanced battery storage solutions and exploring innovative technologies like flow batteries and compressed air energy storage (CAES) to lower operational costs, enhance grid reliability, and support a stable energy transition.

- Develop a policy **framework for decentralized heating solutions,** including standards for equipment and installation. Back this with awareness campaigns and government-sponsored demonstration projects to encourage adoption. **Conduct campaigns** to inform stakeholders about the benefits of decentralized heating systems and sustainable practices, fostering acceptance and effective implementation.

- Provide substantial subsidies and financial incentives to offset the high capital costs of hydrogen production through electrolysis, while fostering international partnerships to reduce expenses through technology transfer and scaling. **Establish RE technology** hubs with dedicated R&D labs to drive innovation in hydrogen production, electrolysis, and related solutions, ensuring cost-effectiveness and long-term sustainability.

- Establish a **comprehensive regulatory framework** for hydrogen production, storage, and utilization, supported by national safety and infrastructure guidelines to enable seamless integration into existing energy systems. Incorporate blockchain technologies to track and verify hydrogen production emissions, ensuring transparency and alignment with international carbon market standards, while fostering investor confidence and global competitiveness.

- **Invest in hydrogen storage and distribution infrastructure**, including pressurized tanks and dedicated pipelines, to support large-scale hydrogen deployment. Collaborate with private sector stakeholders to co-develop scalable and cost-effective solutions while attracting international funding. Leverage green bonds and RE funds to secure investments, working in partnership with global institutions to ensure the financial viability and rapid development of hydrogen infrastructure.

Timeline	Relevant Actor/ Stakeholder	Responsibility
Short-Term (1-2 Years)	Ministry of Energy (MoE) & NEPRA	Establish a centralized authority to harmonize federal and provincial RE policies, ensuring cohesive implementation of ARE Policy, 2019 and IGCEP 2024. Streamline project approvals and reduce delays.
	MoE & AEDB	Operationalize a Single-Window Clearance System to streamline permits and approvals for RE projects, reducing bureaucratic hurdles and accelerating timelines.
	NEPRA	Develop and enforce a transparent National Competitive Bidding Framework with standardized guidelines to enhance investor confidence and cost-efficient project procurement.
	Ministry of Science and Technology (MoST)	Initiate small-scale pilot projects for sector coupling technologies like Power-to-Gas (P2G) and Power-to-Heat (P2H), supported by subsidies and financial incentives.
Medium-Term (3-5 Years)	MoE & Provincial Energy Departments	Align provincial energy policies with national RE goals by conducting workshops, policy revisions, and coordinated stakeholder engagement.
	AEDB & Ministry of Industry & Production (MoIP)	Foster PPPs to establish local manufacturing facilities for RE technologies, including solar panels and wind turbines.
	National Transmission & Dispatch Company (NTDC)	Modernize grid infrastructure to integrate RES effectively, including advanced real-time optimization tools and smart grid technologies.
	MoF & MoE	Launch green financing mechanisms to attract domestic and international investments for energy transition projects.
Long-Term (5-10 Years)	MoE, MoCC & AEDB	Develop and implement carbon market policies aligning RE projects with international carbon credit standards, enabling access to global carbon financing opportunities.
	MoE, MoIP & Private Sector	Establish self-sustaining RE manufacturing zones, providing tax incentives and infrastructure to support local production of renewable technologies.
	MoE, NGOs & Educational Institutions	Conduct large-scale public awareness campaigns and skill-building programs in collaboration with universities to promote RE adoption and long-term capacity building.

Conclusion

In conclusion, Pakistan's renewable energy sector holds immense potential for driving sustainable economic growth and ensuring energy security. Key insights from this report highlight critical areas requiring immediate focus, such as modernizing outdated grid infrastructure, promoting localized manufacturing, and aligning regulatory frameworks to foster renewable integration. Strategic initiatives, such as enhancing electrolyzer efficiency for Green Hydrogen production, leveraging Power-to-Gas (P2G) systems, and investing in decentralized solar solutions, can significantly accelerate the energy transition while addressing challenges like circular debt and high project costs.[1]

With coordinated efforts and strategic investments, Pakistan can harness its renewable energy resources to create a cleaner, more resilient energy future aligned with both national priorities and global sustainability goals.

1 To provide a comprehensive overview of the Renewable Energy Policy Assessment Matrix 2024 and actionable strategies and stakeholder roles, refer to Annex VII and VIII, respectively, for a detailed bird's eye view of the key insights and strategic directions outlined in this report.

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Annexures

Annex I: Methodology of the Report

Methodology Component	Description
Data-Driven Sectoral Analysis	A detailed examination of Pakistan's energy mix, using data from national sources like the Pakistan Economic Survey, NEPRA, and HDIP, as well as international energy reports with focus on renewables in power generation as of 2024.
Energy Capacity and Infrastructure Review	An assessment of Pakistan's installed capacity and transmission and distribution infrastructure, identifying inefficiencies such as energy losses, and evaluating potential for grid modernization to improve reliability and renewable integration.
Policy and Regulatory Assessment	In-depth analysis of critical policies, including IGCEP 2024-2034, National Electricity Plan 2023-27, Fast Track Solar PV Initiatives, and TSEP with focus on energy diversification, capacity expansion, and emissions reduction aligned with sustainability goals.
Trends to Watch in Renewable Energy	Examination of key trends, such as sector coupling (P2X technologies) for integrating renewables into heating and gas production, increasing flexibility and reducing fossil fuel dependency, including review of carbon markets for financing renewable projects through carbon credit trading.
Case Study on Solar PV Uptake	A focused case study exploring the growing role of Solar PV in Pakistan's energy mix, analyzing factors driving adoption combing trend analysis, policy assessment, and case studies to provide a comprehensive development roadmap.

Annex II: Key Guiding Questions

In addressing Pakistan's renewable energy transition, this report seeks to answer fundamental questions about current capabilities, future opportunities, and critical challenges:

Assessing Renewable Energy Progress and Potential: What is the current status of renewable energy in Pakistan, and how have historical trends shaped today's landscape? What are the projections for renewable integration under strategic frameworks like the National Electricity Plan and IGCEP, and how can these targets be effectively met?

Identifying and Overcoming Barriers to Expansion: What are the key regulatory, financial, and infrastructural barriers limiting renewable energy growth in Pakistan? How can targeted policy reforms, financing models, and technological advancements help bridge these gaps and create a conducive environment for renewable expansion?

Leveraging Emerging Trends for a Sustainable Energy Transition: How can sector coupling (Power-to-X) technologies and carbon markets provide transformative pathways for Pakistan's energy system? What are the specific financial and environmental benefits of integrating these trends, and how can they reduce dependency on fossil fuels?

Evaluating the Growth and Impact of Solar PV Adoption: What factors are driving the adoption of solar PV, both at the utility scale and in decentralized, rooftop systems? How can regulatory measures, such as net metering, and systematic tracking mechanisms enhance solar PV's contribution to the national energy mix and address informal market challenges?

Annex III: Policies and Initiatives Guiding Pakistan's Path to Energy Sustainability

Policy/Initiative	Current Scenario	Target	Target Year
Fast Track Solar PV Initiatives, 2022	- Solar PV projects under development: 6,000 MW	- Substitution of expensive imported fossil fuels with solar PV - Solar PV generation on 11 kV feeders - Solarization of public buildings	2025
National Electricity Plan (NE-Plan) 2023-27	- Current renewable energy share in electricity generation is around 31%, with a focus on increasing solar, wind, and hydropower	- Achieve a balanced and sustainable energy mix by 2027 - 100% energy access by 2030 - Increase renewables to 75% by FY-2030	2027, 2030
Integrated Generation Capacity Expansion Plan (IGCEP) 2024-2034	- Total installed capacity of 42,000 MW as of 2024 - Renewables (excluding hydro) contribute 20% to total capacity	- Increase total installed capacity to 57,000 MW by 2034 - Target renewable capacity growth with solar and wind contributing 10% to the energy mix - 46% of the energy mix from hydropower	2034
Nationally Determined Contributions (NDC)	- Current renewable energy share around 31% (including Bagasse and hydro)	- Achieve 60% renewable energy share (including hydro) in the overall energy mix by 2030	2030
Transmission System Expansion Plan (TSEP) 2024-34	- Existing transmission infrastructure strained with increasing renewable energy capacity	- Expand transmission lines, substations, and associated infrastructure to support future demand - Ensure stability with reactive power compensation, grid solutions, and voltage control - Projected cost for grid expansion and reinforcement: USD 15 billion	2024-2034

Annex IV: Key Short-, Medium- & Long-Term Recommendations for Pakistan's Energy Transition

Timeline	Recommendations	Responsible Entities	Expected Outcomes
Short-Term (1-2 Years)	Streamline regulatory processes through a single-window system.	Federal and provincial governments	Faster approvals and investor confidence.
	Introduce concessional financing and credit guarantee mechanisms.	Ministry of Finance, InfraZamin, NEPRA	Reduced financing barriers for smaller developers.
	Launch pilot projects in DERs.	Private sector, energy agencies	Scalable renewable solutions in underserved areas.
	Implement competitive bidding frameworks.	NEPRA, IPPs	Cost-efficient renewable energy procurement.
Medium-Term (3-5 Years)	Upgrade grid infrastructure with smart grids and metering.	NTDC, DISCOs, Ministry of Energy	Enhanced grid stability and renewable integration.
	Develop local manufacturing for renewable components.	Ministry of Industries, private sector	Reduced import reliance, job creation.
	Harmonize federal and provincial policies.	Federal/provincial energy departments	Aligned governance, reduced delays.
	Expand capacity-building programs.	Training institutes, energy sector experts	Improved technical expertise in renewables.

Long-Term (5-10 Years)	Integrate sector coupling technologies (Power-to-X).	R&D institutions, private sector	Enhanced energy flexibility and storage options.
	Establish carbon markets for renewable financing.	SECP, Ministry of Climate Change	Sustainable project funding through carbon credits.
	Achieve energy independence through local renewable production.	Ministry of Energy, private sector	Reduced import reliance, energy security.
	Promote regional energy trade and cooperation.	SAARC, bilateral agreements	Cross-border trade and regional collaboration.

Annex V- Key Energy Policies and Reforms in Pakistan

Policy/Initiative	Implementation Period	Key Objectives	Recent Developments
National Electricity Plan (2023-2027)	2023-2027	Modernize power infrastructure and improve efficiency.	Introduced a framework for cleaner energy sources, infrastructure upgrades, and data-driven forecasting tools for energy optimization.
Fast Track Solar PV Initiative (2022)	2022 onwards	Accelerate solar adaptation for residential and large-scale projects.	Several residential and commercial installations initiated, but large-scale projects lag behind targets.
Integrated Generation Capacity Expansion Plan (IGCEP 2024-34)	2024-2034	Ensure optimal power generation capacity with a focus on hydropower and local energy sources.	PLEXOS-based modeling introduced for demand-supply scenarios. Project prioritization under review for improved alignment with targets.
Transmission System Expansion Plan (TSEP 2024-2034)	2024-2034	Upgrade transmission networks to reduce losses and meet future energy demands.	Advanced transmission corridors planned for regional interconnectivity and renewable integration.
Competitive Trading Bilateral Contract Market (CTBCM)	Approved in 2023	Shift from single-buyer model to multi-buyer, multi-seller system for cost transparency and efficiency.	Operational framework finalized, NEPRA and CPPA launched workshops to train market participants.

Annex VI - Comparison of IGCEP 2024-34 and Previous IGCEP Plan

Feature	IGCEP 2024-34	Previous IGCEP
Total Installed Capacity by 2034	57,000 MW	~50,000 MW
Investment Requirement	$72 billion	$50-55 billion
Projected Demand Increase (2034)	46%	30-35%
Hydropower Share in Energy Mix	46%	35-40%
Solar PV Addition	5,539 MW (2,107 MW from net metering)	~3,000 MW
Variable Renewable Energy (VRE)	10%	5-7%
Indigenous Fuel Mix	31%	~20%
Imported Fuel Reliance	Significant reduction	High reliance on imported fuels

Annex VII: Renewable Energy Policy Assessment Matrix 2024

RE Targets of Pakistan	Actual Achievements	Barriers	Policies Deployed vis-à-vis Barriers	Best Practices to Overcome Barriers	Policy Gaps & Solutions
Integrated Generation Capacity Expansion Plan (IGCEP) 2024-34 Target: 57,000 MW total installed capacity, with 10% VRE and 46% hydro by 2034	Current installed capacity: 42,000 MW VRE (solar and wind) contributes ~20% of RE, and hydro contributes ~31%	Planning and Capacity – Slow progress in scaling VRE capacity due to inadequate long-term planning tools	IGCEP 2024-34 sets progressive VRE capacity expansion targets, specifically for solar and wind, aiming for 10% share by 2034	Develop an adaptive capacity planning model, conducting annual demand assessments and revising IGCEP targets accordingly	Policy Gap: Limited flexibility in capacity planning Solution: Introduce an annual review and adjustment mechanism for IGCEP to account for evolving energy demands and technology costs
		Financial Constraints – Limited funds for VRE-specific infrastructure such as battery storage and smart grids	IGCEP aligns with TSEP for dedicated financing to improve VRE integration and reduce transmission bottlenecks	Promote blended finance models involving PPPs to share costs for VRE infrastructure	Policy Gap: Inadequate financing for VRE infrastructure Solution: Establish concessional loan programs with SBP and MoF, focused on VRE technologies and grid enhancement
National Electricity Plan (NE-Plan) 2023-27 Target: Achieve 100% electricity access, with 75% RE by 2030 (VRE and hydro combined)	RE constitutes ~31% of electricity generation VRE share remains under 10% across national grid	Regulatory Misalignment – Federal and provincial inconsistencies hinder RE expansion and energy access	NE-Plan introduces an Integrated Energy Plan (IEP) to align policy efforts at federal and provincial levels	Establish a centralized regulatory body for harmonized VRE and hydro policies, streamlining policy execution across regions	Policy Gap: Fragmented regulatory framework Solution: Form a regulatory task force for unified RE policy oversight and streamlined provincial collaboration
		Affordability – High electricity tariffs impact energy access, especially in remote and rural areas	NE-Plan's Universal National Electrification (UNE) program targets 100% energy access with subsidies for low-income regions	Design targeted subsidies for rural and underserved areas and deploy off-grid VRE systems to lower costs	Policy Gap: High costs limit energy access Solution: Roll out targeted subsidies and off-grid VRE incentives specifically for rural electrification
Fast Track Solar PV Initiatives 2022 Target: 6,000 MW additional solar PV capacity by 2025	Approximately 2,000 MW of solar PV projects initiated; focus on solarizing public buildings and feeder lines	High Capital Costs – Initial costs for solar technology and low subsidy availability hinder large-scale adoption	Fast Track Initiatives utilize competitive bidding processes to reduce installation costs and ensure cost-effective deployment	Introduce VAT exemptions and reduce import duties on solar components to make projects financially viable	Policy Gap: Insufficient financial incentives for solar adoption Solution: Expand fiscal benefits, including tax credits and accelerated depreciation for solar investors
		Technical Expertise – Shortage of skilled labor for solar PV installation and maintenance	Fast Track Initiatives mandate technical training partnerships with local institutions	Partner with vocational and technical institutes to develop a skilled workforce for solar PV installation and maintenance	Policy Gap: Lack of skilled workforce Solution: Establish skill-building programs with a focus on solar PV technologies through technical institutes and AEDB
Transmission System Expansion Plan (TSEP) 2024-34 Target: Modernize grid to support 57,000 MW with VRE integration by 2034	Current grid faces challenges with VRE integration, particularly in VRE-rich regions like Sindh and Balochistan	Grid Infrastructure – Overloaded transmission lines, lack of reactive power support, and outdated technology	TSEP 2024-34 proposes phased upgrades, including advanced grid management systems (SCADA) and reactive power compensation	Deploy energy storage and SCADA systems to manage VRE variability and stabilize grid performance	Policy Gap: Outdated infrastructure limits VRE potential Solution: Establish a dedicated budget for advanced grid solutions, with international financing support
		Approval Delays – Prolonged project approval timelines for transmission expansion	TSEP establishes streamlined approval processes for key transmission projects	Create a single-window approval process for TSEP projects across federal and provincial jurisdictions	Policy Gap: Inefficient approval processes for grid upgrades Solution: Implement centralized, fast-track approvals for critical transmission expansions in VRE-intensive regions

Annex VIII: Key Insights and Strategic Directions for Pakistan's Renewable Energy Transition

Key Insights	Description
Hidden Solar Capacity from Decentralized Growth	Pakistan's solar PV market has expanded significantly through decentralized installations like rooftop systems. Official AEDB data reports 1,244 MW of capacity in 2023, but informal estimates suggest the actual figure exceeds 2,300 MW.
Solar Irradiation and Energy Potential	Pakistan receives 4.5-6.5 kWh/m²/day of solar irradiation with ~300 sunny days annually. Regions like Sindh and Balochistan could generate over 1,000 GW annually if fully utilized, addressing the ~5,000 MW energy shortfall.
Rising Solar Imports Reflecting Demand Surge	Solar imports increased by 77% from January 2022 to December 2023, with Pakistan becoming the third-largest global importer. In December 2023, imports grew by 156% YoY, reflecting rising demand for solar solutions.
Shifting Net Metering Policies and Market Dynamics	NEPRA's 2015 net metering policy spurred rooftop solar adoption, but recent shifts to gross metering and reduced buyback rates (~30%-40% lower returns) may discourage smaller installations.
Recognizing Gas Supply Challenges	Depleting gas reserves and rising prices highlight the need for alternative energy solutions, underscoring the urgency of diversifying Pakistan's energy mix.
Promoting Power-to-Gas (P2G) Technology	Power-to-Gas (P2G) systems enable the conversion of surplus renewable energy into hydrogen and synthetic methane, offering a sustainable alternative to traditional gas sources.
Green Hydrogen Production	Electrolysis powered by renewable energy sources like wind and solar offers a transformative pathway for producing Green Hydrogen, significantly reducing carbon emissions.
Blue Hydrogen Consideration	Blue Hydrogen, produced from fossil fuels with carbon capture and storage (CCS), serves as a transitional solution until Green Hydrogen becomes economically viable.
Methanation Process	Incorporating methanation into P2G systems allows for the production of synthetic methane, contributing to reduced net emissions and enhancing energy system flexibility.
Improving Electrolyzer Efficiency	Investing in advanced electrolyzer technology will improve the efficiency of hydrogen production, reducing costs and enhancing scalability.
Carbon Border Adjustment Mechanism (CBAM)	Monitoring policies like the EU's CBAM is essential to ensure competitiveness in hydrogen exports and align domestic policies with global standards.
Outdated Grid Infrastructure	Pakistan's aging grid infrastructure, designed for centralized power systems, is inadequate for renewable energy integration, causing voltage fluctuations and energy curtailment.
Insufficient Transmission Capacity	Overloaded transmission lines and insufficient capacity in renewable-rich regions, such as Sindh and Balochistan, hinder energy transfer to demand centers, limiting the potential of renewable energy projects.
Underinvestment in Grid Modernization	Long payback periods and regulatory uncertainties have deterred investments in upgrading grid infrastructure, perpetuating inefficiencies and slowing renewable energy integration.
Limited Local Manufacturing Capacity	Pakistan's dependence on imported renewable energy components increases project costs and limits technology transfer, stifling innovation and job creation.
High Import Duties and Currency Volatility	Import duties, tariffs, and currency devaluation increase the cost of renewable energy projects by 25-30%, making them less competitive compared to conventional energy sources.
Circular Debt and Payment Delays	Delayed payments to renewable IPPs due to circular debt create financial insecurity, discouraging investment and slowing renewable energy development.
Weak Technical Feasibility Studies	Inadequate and outdated feasibility studies increase project risks and costs, delaying implementation and reducing investor confidence.
Regulatory Barriers and Institutional Delays	Complex and inconsistent regulatory frameworks slow project approvals, increasing uncertainty for investors and developers in the renewable energy sector.
Lack of Advanced Grid Management	Inefficient grid management practices, including poor forecasting and lack of real-time monitoring, hinder optimal use of renewable energy, leading to increased curtailment and higher costs.

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