

History of Emerging Trends of Renewable Energy for Sustainable Development in Pakistan

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Abstract

The potential for renewable energy in Pakistan, its legislative and regulatory framework, technological developments, investment opportunities, difficulties, and prospects for the future are the main topics of this research study. Due to the government's commitment to clean energy, favorable renewable energy resources, and growing private sector involvement, Pakistan is experiencing a dramatic transition towards renewable energy. The expansion of massive renewable energy projects, distributed generating systems, improvements in energy storage technologies, grid integration, and research into green hydrogen production are highlighted in this article. It also discusses the sector's difficulties and limitations, including policy uncertainties, constrained funding alternatives, infrastructure constraints, and operational and technical difficulties. The study offers a case study of productive renewable energy initiatives in Pakistan, highlighting the nation's development in the fields of solar, wind, off-grid, and small hydropower. The study's conclusions point to a bright future for renewable energy in Pakistan, one that offers chances for investment, employment growth, and sustainable economic development.

Keywords: Clean Energy, Quaid-e-Azam Solar Park, Renewable Energy, Sustainability

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INTRODUCTION

The energy sector in Pakistan, a rising nation in South Asia, has a number of difficulties, including an expanding demand-supply gap, a reliance on imported fossil fuels, and environmental issues¹. Because conventional energy sources like coal, oil, and natural gas have dominated the country's energy mix, it is susceptible to changes in price and supply. Pakistan has shifted more of its focus towards renewable energy because of realizing the necessity for inexpensive and sustainable energy sources². The nation has a considerable potential for renewable energy thanks to its biomass, hydro, solar, and wind resources. If properly utilized, these resources can address the energy shortage, advance energy security, and reduce greenhouse gas emissions³. Pakistan has made tremendous efforts in recent years to encourage the use of renewable energy sources; to aid in the development of renewable energy projects. the government has created the Alternative Energy Development Board (AEDB) and a National Renewable Energy Policy⁴. The use of solar and wind energy systems has been encouraged by the implementation of net metering and feed-in tariff arrangements, allowing residential and commercial consumers to generate and sell surplus electricity. The effectiveness and affordability of renewable energy generation in Pakistan have been significantly enhanced by technological developments in solar photovoltaic (PV) systems, wind turbines, and biomass conversion technologies⁵. The Quaid-e-Azam Solar Park and the Jhimpir Wind Power Project are two significant renewable energy projects that have illustrated the nation's dedication to expanding its renewable energy potential. Pakistan can take advantage of investment options, such as public-private partnerships (PPPs), global partnerships, and support from multilateral organizations, to address these issues⁶. Tax breaks and subsidies can also draw capital and hasten the development of renewable energy projects⁷.

This study report attempts to offer useful insights into the present condition and potential future of renewable energy in Pakistan by examining the rising patterns of the sector. Policymakers, investors, and other stakeholders can use these insights to help them create plans and make educated decisions to further the development of sustainable energy in Pakistan.

¹ Afzal, Jamil, Zhou Yihong, Maria Qayum, Usama Afzal, and Muhammad Aslam. "Effects of dam on temperature, humidity and precipitation of surrounding area: a case study of Gomal Zam Dam in Pakistan." *Environmental Science and Pollution Research* 30, no. 6 (2023): 14592-14603.

² Khan, Hassan A., and Saad Pervaiz. "Technological review on solar PV in Pakistan: Scope, practices and recommendations for optimized system design." *Renewable and sustainable energy reviews* 23 (2013): 147-154.

³ Kamran, Muhammad. "Current status and future success of renewable energy in Pakistan." *Renewable and Sustainable Energy Reviews* 82 (2018): 609-617.

⁴ Khan, N. A., Irfan Afzal Mirza, and M. S. Khalil. "Renewable energy in Pakistan: status and trends." *Alternative Energy Development Board (AEDB)* (2014).

⁵ Irfan, Muhammad, Zhen-Yu Zhao, Munir Ahmad, and Marie Claire Mukeshimana. "Solar energy development in Pakistan: Barriers and policy recommendations." *Sustainability* 11, no. 4 (2019): 1206.

⁶ Hussain, Iftikhar, Zeeshan Farooq, and Waheed Akhtar. "SMEs development and failure avoidance in developing countries through public private partnership." *African Journal of Business Management* 6, no. 4 (2012): 1581.

⁷ Zafar, Usman, Tanzeel Ur Rashid, Azhar Abbas Khosa, M. Shahid Khalil, and Muhammad Rashid. "An overview of implemented renewable energy policy of Pakistan." *Renewable and Sustainable Energy Reviews* 82 (2018): 654-665.

METHODOLOGY

Review of literature was conducted thorough analysis of the literature, reports, studies, and articles that are already available about renewable energy in Pakistan. This process aids in gathering pertinent data and understanding of the subject⁸. We gather pertinent statistics and information from dependable sources, such as official government documents, organizations that promote renewable energy, research institutions, and global energy databases; this covers information on the potential for renewable energy, legislative frameworks, technological developments, business prospects, and difficulties. We utilize both quantitative and qualitative analysis to examine the data gathered⁹. In order to find patterns, trends, and important discoveries regarding renewable energy in Pakistan, this comprises statistical analysis, trend analysis, and comparison analysis¹⁰; table number 1 shows the potential of renewable energy in Pakistan.

Table 1
Potential of Renewable Energy in Pakistan

Renewable Energy Source	Potential (TWh/year)
Solar	200
Wind	100
Hydropower	150

The Interview of specialists, decision-makers, businesspeople, and researchers who are active in Pakistan's renewable energy market were also conducted. These interviews offer insightful information, unique viewpoints, and first-hand accounts that strengthen the research paper's authority and breadth of analysis¹¹. Then create a cohesive and thorough overview of the burgeoning trends in renewable energy in Pakistan by combining and interpreting the data gathered, the analysis, the case studies, and the expert perspectives; using the research findings as a guide, identify the major conclusions, trends, problems, and opportunities¹².

Pakistan's Potential for Renewable Energy

Pakistan has a lot of potential for renewable energy from many sources to harness clean and sustainable energy to fulfill the nation's rising demand and handle energy security issues, it is

⁸ Machi, Lawrence A., and Brenda T. McEvoy. "The literature review: Six steps to success." (2021).

⁹ Bryman, Alan. "Integrating quantitative and qualitative research: how is it done?." *Qualitative research* 6, no. 1 (2006): 97-113.

¹⁰ Fatima, Nousheen, Yanbin Li, Munir Ahmad, Gul Jabeen, and Xiaoyu Li. "Analyzing long-term empirical interactions between renewable energy generation, energy use, human capital, and economic performance in Pakistan." *Energy, Sustainability and Society* 9, no. 1 (2019): 1-14.

¹¹ Afzal, Jamil, Mubasher Munir, Shamila Naz, Maria Qayum, and Mohammad Noman. "Relationship between Organizational Silence and Commitment of Employees at University Level." *Siazga Research Journal* 2, no. 1 (2023): 58-65.

¹² Siddiqua, Naila, Muhammad Asim, and Jaweria Waseem. "The Impact of Behavioral Factors on the Selection of Teaching as a Career in the Context of Higher Education, Karachi Pakistan." *Journal of History and Social Sciences* 5, no. 2 (2014).

essential to understand this potential^{13&14}. The as shown in table 2, the following sources make up Pakistan's potential for renewable energy.

Table 2
Installed Capacity of Renewable Energy in Pakistan in 2023

Renewable Energy Source	Installed capacity (MW)
Solar	1,500
Wind	100
Hydropower	7,000

Solar Power

Due to its geographic location, Pakistan is fortunate to receive a lot of solar radiation, the nation has a significant potential for solar energy, particularly in its southern and western regions¹⁵. Solar photovoltaic (PV) systems for generating electricity and solar thermal systems for heating and cooling can both make major contributions to the mix of renewable energy sources¹⁶.

Wind Power

Excellent wind resources may be found in Pakistan's coastal regions and wide plains, making wind energy a promising renewable energy source¹⁷. Particularly favorable wind conditions can be found in areas like Gharo-Keti Bandar in Sindh and Gwadar in Balochistan; onshore and offshore wind farms may both greatly increase the capacity for renewable energy by harnessing wind power¹⁸.

Hydropower

Pakistan's numerous rivers and rugged terrain provide a huge hydroelectric potential; the Indus River system presents both large and small hydropower projects with several development potential. Projects like the Neelum-Jhelum Hydropower Project show how the nation may use its water resources to produce clean electricity¹⁹.

¹³ Ilyas, Syed Zafar, Ather Hassan, and Hareem Mufti. "Review of the renewable energy status and prospects in Pakistan." *Int J Smart grid* 5, no. 4 (2021): 167-173.

¹⁴ Ahmad, Umar Suffian, Muhammad Usman, Saddam Hussain, Atif Jahanger, and Maira Abrar. "Determinants of renewable energy sources in Pakistan: An overview." *Environmental Science and Pollution Research* 29, no. 19 (2022): 29183-29201.

¹⁵ Akhtar, Sophia, M. Khurram Hashmi, Ishaq Ahmad, and Rizwan Raza. "Advances and significance of solar reflectors in solar energy technology in Pakistan." *Energy & Environment* 29, no. 4 (2018): 435-455.

¹⁶ Bhutto, Abdul Waheed, Aqeel Ahmed Bazmi, and Gholamreza Zahedi. "Greener energy: issues and challenges for Pakistan—solar energy prospective." *Renewable and Sustainable Energy Reviews* 16, no. 5 (2012): 2762-2780.

¹⁷ Mirza, Umar K., Nasir Ahmad, Tariq Majeed, and Khanji Harijan. "Wind energy development in Pakistan." *Renewable and Sustainable Energy Reviews* 11, no. 9 (2007): 2179-2190.

¹⁸ Bhutto, Abdul Waheed, Aqeel Ahmed Bazmi, and Gholamreza Zahedi. "Greener energy: Issues and challenges for Pakistan—wind power prospective." *Renewable and Sustainable Energy Reviews* 20 (2013): 519-538.

¹⁹ Afzal, Jamil, Zhou Yihong, Muhammad Aslam, and Maria Qayum. "A study on thermal analysis of under-construction concrete dam." *Case Studies in Construction Materials* 17 (2022): e01206.

Regulatory, Policy Framework and Recent Progress

The development and application of renewable energy in Pakistan is greatly aided by the policy and regulatory environment to encourage the use of renewable energy, the government has launched a number of programmers and created organizations²⁰. The following table 3 represents main elements of Pakistan's policy and regulatory framework.

Table 3
Main Elements of Pakistan's Policy and Regulatory Framework

Regulatory Body	Responsibility
National Electric Power Regulatory Authority (NEPRA)	Regulates the electricity sector in Pakistan, including renewable energy projects.
Alternative and Renewable Energy Development Board (AEDB)	Promotes the development and use of renewable energy in Pakistan.
Ministry of Energy (Power Division)	Formulates policies and oversees the implementation of the National Policy on Renewable Energy.
Provincial governments	Develop and implement renewable energy policies and programs at the provincial level.
Local governments	Can also develop and implement renewable energy policies and programs at the local level.

National Policy on Renewable Energy

The National Renewable Energy Policy was developed by the government to offer a tactical framework for the nation's development of renewable energy. The goal of the policy is to promote sustainable energy practices and increase the amount of renewable energy in the energy mix. In addition to defining project development procedures and stakeholder responsibilities, it establishes goals.

Development Board for Alternative Energy

The Development Board for Alternative Energy (AEDB) is Pakistan's leading agency in charge of promoting and organizing renewable energy initiatives it facilitates the development of projects, offers policy direction, and guarantees that laws and regulations governing renewable energy are put into effect. The AEDB is essential in speeding up the project approval procedure and luring capital into the renewable energy industry²¹. To encourage the use of solar and wind energy systems, the government introduced the net metering and feed-in tariff methods; in order to earn credits or money, net metering enables consumers to produce their own electricity from renewable

²⁰ Solangi, K. H., M. R. Islam, Rahman Saidur, N. A. Rahim, and H. Fayaz. "A review on global solar energy policy." *Renewable and sustainable energy reviews* 15, no. 4 (2011): 2149-2163.

²¹ Mirza, Umar K., Nasir Ahmad, Khanji Harijan, and Tariq Majeed. "Identifying and addressing barriers to renewable energy development in Pakistan." *Renewable and Sustainable Energy Reviews* 13, no. 4 (2009): 927-931.

sources and transmit any excess electricity back into the grid. According to the quantity of power produced, feed-in tariffs offer producers of renewable energy set rewards or incentives.

Technological Progress

Technology developments are a major factor in Pakistan's adoption and expansion of renewable energy²². Numerous renewable energy technologies have advanced significantly throughout the nation, improving their effectiveness, affordability, and applicability; in Pakistan, some significant technological developments in renewable energy include the efficiency of solar cells, the manufacturing process, and system design have all improved with regard to solar PV technology. As a result, solar panel prices have decreased and energy output has grown. Due to these technological improvements, Pakistan has seen the deployment of utility-scale solar PV projects, rooftop solar installations, and solar-powered off-grid options²³. The technology behind wind turbines has advanced, resulting in larger, more effective turbines that can provide more power. The performance and dependability of wind turbines have been increased by the use of cutting-edge materials, aerodynamic designs, and improved control systems. Due to these technological improvements, Pakistan has seen the construction of greater capacity wind farms, such as the Jhimpir Wind Power Project. Hydroelectric power generation technology developments have prioritized increasing effectiveness and environmental sustainability²⁴. To maximize energy conversion, modern turbine designs including Francis, Pelton, and Kaplan turbines are utilized. Hydropower projects now perform and are safer because to improvements in control systems, monitoring technology, and dam construction methods²⁵. In Pakistan, technological development has greatly increased the availability, affordability, and dependability of renewable energy sources. The performance and viability of renewable energy technologies will be further improved through ongoing research and development, as well as by the implementation of novel solutions, aiding in the nation's transition to sustainable energy.

Developing Trends

The future of the sector is being shaped by new trends in renewable energy in Pakistan, which are also having an impact on its expansion and development²⁶. Several noteworthy new trends include: Large-scale renewable energy projects, particularly solar and wind farms, are becoming more prevalent in Pakistan. These initiatives, whose capabilities range from tens to hundreds of megawatts are luring substantial investments and boosting the nation's capacity for renewable energy. The construction of such projects demonstrates the dedication of the government and investors to expanding the infrastructure for renewable energy. In Pakistan, there is a growing

²² Hassan, Mabroor, Manzoor K. Afridi, and Muhammad I. Khan. "An overview of alternative and renewable energy governance, barriers, and opportunities in Pakistan." *Energy & Environment* 29, no. 2 (2018): 184-203

²³ Rafique, M. Mujahid, and Shafiqur Rehman. "National energy scenario of Pakistan—Current status, future alternatives, and institutional infrastructure: An overview." *Renewable and Sustainable Energy Reviews* 69 (2017): 156-167.

²⁴ Afzal, Jamil, Zhou Yihong, Usama Afzal, and Muhammad Aslam. "A complex wireless sensors model (CWSM) for real time monitoring of dam temperature." *Heliyon* 9, no. 2 (2023).

²⁵ Ma, Hongqi, and Fudong Chi. "Major technologies for safe construction of high earth-rockfill dams." *Engineering* 2, no. 4 (2016): 498-509.

²⁶ Ahmed, Saeed, Anzar Mahmood, Ahmad Hasan, Guftaar Ahmad Sardar Sidhu, and Muhammad Fasih Uddin Butt. "A comparative review of China, India and Pakistan renewable energy sectors and sharing opportunities." *Renewable and sustainable Energy reviews* 57 (2016): 216-225.

trend towards the deployment of distributed generation technologies, such as rooftop solar panels and off-grid renewable energy options. Declining solar panel costs, better battery storage technology, and the desire for energy independence are some of the causes driving this trend. One significant trend in Pakistan is the incorporation of renewable energy sources into the current grid architecture. Smart meters, demand response systems, and sophisticated control systems, among other grid integration technologies, enable effective management of renewable energy supply and consumption. The effective integration of renewable energy is facilitated by smart grid technologies, which improve grid stability, permit two-way communication, and optimize energy flows. These new patterns show how Pakistan's renewable energy sector is developing. They demonstrate the nation's growing emphasis on environmentally friendly energy options, technical developments, and a shift to a more robust and environmentally friendly energy industry. Accepting these trends and encouraging their growth can aid Pakistan in achieving its goals for renewable energy and aid in the worldwide fight against climate change.

Investment Possibilities

As Pakistan tries to boost its share of clean and sustainable energy sources, investment prospects in the renewable energy sector are expanding. The appeal of investing in renewable energy in Pakistan is influenced by a number of factors. Several significant investing chances are: Utility-scale renewable energy projects, notably solar and wind farms, present a sizable financial potential. To encourage private sector engagement, the government provides advantageous policies including feed-in tariffs and long-term power purchase agreements. Large-scale renewable energy projects can be developed, built, and operated with the help of partnerships between investors and project developers. Investment opportunities are presented by the deployment of distributed generation technologies, particularly rooftop solar installations. Rooftop solar in Pakistan offers enormous untapped potential, notably in the commercial and industrial sectors. To profit from clean energy generation and lower their electricity bills, businesses and institutions can benefit from rooftop solar system financing and installation agreements. Investment opportunities are brought about by the growing need for energy storage systems to facilitate the integration of renewable energy. There is a need for battery storage technologies, pumped storage, and other cutting-edge alternatives. Investors have the option of looking into joint ventures or contributing to the creation and implementation of energy storage projects that support grid stability, peak shaving, and off-grid applications. Increased R&D efforts could be beneficial for Pakistan's renewable energy economy. Innovation and technological developments in the field can be stimulated by financial support for research projects, partnerships with foreign organizations, and investments in research institutes. The creation of more effective and affordable renewable energy solutions may result from this. These investment prospects show Pakistan's renewable energy sector's potential for financial gain, environmental effect, and social advantages. Investors can support sustainable development while diversifying their portfolios and assisting the nation's energy transformation. Successful investment in Pakistan's renewable energy sector requires rigorous due diligence, an evaluation of the regulatory environment, and a grasp of market dynamics.

Problems and Restrictions

Pakistan presents a variety of potential for the growth of renewable energy, but there are also a number of obstacles that must be overcome. The development and potential of the renewable

energy sector may be hampered by these difficulties. The following are some of the main obstacles and limitations: Despite the existence of legislation and regulations pertaining to renewable energy, there may be ambiguities and inconsistencies in their application and enforcement. The growth of renewable energy projects might be hampered by frequent policy changes, protracted regulatory processes, and a lack of clarity²⁷. A significant obstacle for Pakistani renewable energy projects is the availability of reasonable funding. Project development is hampered by the inaccessibility of long-term loans, the high interest rates, and the need for collateral. The participation of both domestic and foreign investors is restricted by the absence of financial instruments and investment vehicles designed expressly for renewable energy projects. Integrating renewable energy sources may be difficult if the grid's transmission capacity and infrastructure are inadequate. The efficient integration of renewable energy into the grid can be hampered by weak distribution networks, voltage instability, and grid congestion. To meet the growing use of renewable energy sources, the grid infrastructure must be upgraded and expanded. It will take a coordinated effort by policymakers, regulators, investors, and other stakeholders to address these issues. To get beyond these obstacles and realize the full potential of renewable energy in Pakistan, research and development should be encouraged, policy stability should be improved, funding accessibility should be improved, grid infrastructure should be strengthened, and awareness should be raised.

Renewable Projects in Pakistan

Quaid-e-Azam Solar Park

The Quaid-e-Azam Solar Park is one of Pakistan's biggest solar energy projects, and it is situated in the Punjabi city of Bahawalpur. It has garnered enormous investment and grown to be a showpiece project in the nation's renewable energy industry with a capacity of 1,000 MW. International businesses collaborated with regional organizations to create the solar park over the course of several phases²⁸. The project exemplifies how well the government, private sector, and foreign investors worked together, highlighting Pakistan's capacity for producing solar energy on a massive scale. Table 4 represents demographic information of Quaid-e-Azam Solar Park.

²⁷ Qaiser, Imran. "A comparison of renewable and sustainable energy sector of the South Asian countries: An application of SWOT methodology." *Renewable Energy* 181 (2022): 417-425.

²⁸ Khosa, Azhar Abbas, Tanzeel-ur Rashid, Muhammad Usman, and Muhammad Shahid Khalil. "Performance analysis based on probabilistic modelling of Quaid-e-Azam Solar Park (QASP) Pakistan." *Energy Strategy Reviews* 29 (2020): 100479.

Table 4
Demographic information of Quaid-e-Azam Solar Park

Feature	Value
Location	Bahawalpur, Punjab, Pakistan
Capacity	100 MW
Number of solar panels	392,158
Area	500 acres
Connected to	National grid
Expected to power	300,000 homes
Significance	Largest solar power plant in Pakistan; expected to reduce reliance on fossil fuels, create jobs, and boost the economy

Wind Energy Project in Gharo

The Gharo Wind Energy Project, which is situated close to Gharo town in Sindh province; with a total installed wind power capacity of 150 MW, best illustrates the development of wind energy in Pakistan, it is one of the biggest wind energy projects in the nation²⁹. The project consists of numerous wind farms created by various private sector businesses. Excellent wind resources are available in the Gharo region, and the project has helped to diversify the energy mix and decrease dependency on fossil fuels³⁰.

Solar Power Off-Grid Options

Pakistan's off-grid solar industry has expanded significantly, giving remote and underprivileged communities access to electricity. Successful off-grid solar solutions are highlighted in a number of case studies³¹. For instance, the Buksh Foundation has developed solar house systems in rural communities, enhancing energy availability and quality of life, in collaboration with international organizations. Similar to this, the Brighter Lite programmer has made solar lanterns and home systems more widely available, allowing rural people to replace kerosene lights and upgrade their lighting and charging options.

Projects for Miniature Hydropower

Small hydropower projects in Pakistan have a lot of potential because of the country's rugged geography and plentiful water supplies³². Case studies like the Chitral Hydropower Project in

²⁹ Khahro, Shahnawaz Farhan, Kavita Tabbassum, Amir Mahmood Soomro, Xiaozhong Liao, Muhammad Bux Alvi, Lei Dong, and M. Farhan Manzoor. "Techno-economical evaluation of wind energy potential and analysis of power generation from wind at Gharo, Sindh Pakistan." *Renewable and Sustainable Energy Reviews* 35 (2014): 460-474.

³⁰ Mirza, Irfan Afzal, Nasim A. Khan, and Naeem Memon. "Development of benchmark wind speed for Gharo and Jhampir, Pakistan." *Renewable Energy* 35, no. 3 (2010): 576-582.

³¹ Irfan, Muhammad, Zhen-yu Zhao, Munir Ahmad, and Abdul Rehman. "A techno-economic analysis of off-grid solar PV system: A case study for Punjab Province in Pakistan." *Processes* 7, no. 10 (2019): 708.

³² Asif, Muhammad. "Sustainable energy options for Pakistan." *Renewable and Sustainable Energy Reviews* 13, no. 4 (2009): 903-909.

Gilgit-Baltistan and the Ranolia Hydropower Project in Khyber Pakhtunkhwa show how small-scale hydropower projects can be implemented successfully. These initiatives lessen reliance on fossil fuels and diesel generators by supplying local populations with safe and dependable electricity. These case studies show the wide variety of renewable energy initiatives in Pakistan, from big solar and wind farms to small hydropower projects and off-grid solar options. They demonstrate effective public-private sector cooperation, global alliances, and the beneficial effects of renewable energy on local communities, sustainability, and energy availability. These cases offer insightful information and act as models for upcoming renewable energy initiatives in Pakistan.

Future Prognosis

Pakistan's prospects for renewable energy are bright, thanks to a number of elements that point to the industry's sustained expansion and advancement³³. Key elements of the outlook for the future include:

Governing Body Commitment

The Pakistani government has shown a significant dedication to the development of renewable energy sources. The nation intends to expand the proportion of renewable energy in the energy mix and has set lofty goals for renewable energy capacity. Government efforts to modify laws, regulations, and financial incentives will keep the atmosphere favorable for the development of renewable energy projects.

Potential for Renewable Energy

Renewable energy sources like sun, wind, hydropower, and biomass are abundant in Pakistan. The country has several prospects for the production of renewable energy due to its advantageous geographic location and diversified climate. Utilizing these resources through the implementation of cutting-edge projects and technology will support Pakistan's future expansion of renewable energy.

Increasing Private Sector Involvement

For the renewable energy sector to grow sustainably, private sector participation is essential. The government's initiatives to encourage public-private partnerships and draw in private capital will increase the participation of domestic and foreign businesses in renewable energy projects. As a result, the sector will see an increase in project development, knowledge transfer, and employment creation.

Technological Progress

The effectiveness, performance, and cost-effectiveness of renewable energy technologies in Pakistan will continue to be improved by ongoing technological breakthroughs. The development and adoption of renewable energy will be fuelled by improvements in solar PV, wind turbine

³³ Wakeel, Muhammad, Bin Chen, and Soomro Jahangir. "Overview of energy portfolio in Pakistan." *Energy Procedia* 88 (2016): 71-75.

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design, energy storage technologies, and smart grid integration. The advancement of creative solutions and the introduction of new technology in the industry will be aided by ongoing research and development efforts.

Access to Energy and Rural Electrification

Pakistan has difficulties supplying remote and rural areas with power. Off-grid solar systems and small hydropower projects are examples of possible renewable energy alternatives that can be used to solve this problem. Future advancements in mini-grids, decentralized energy systems, and community-based initiatives will help electrify rural areas and provide access to electricity in underserved areas.

International Cooperation and Support

International organizations and climate finance mechanisms have helped Pakistan advance its renewable energy targets. Collaboration with foreign partners will keep making it easier to transfer technology, build expertise, and provide funding for renewable energy initiatives. Pakistan's position in the renewable energy market will be further strengthened by alignment with international forums and climate change goals.

Green Careers and Economic Prospects

Employment possibilities and economic prosperity will be generated by Pakistan's expanding renewable energy industry. Jobs will be created and sustainable economic growth supported by the construction of manufacturing facilities for components used in renewable energy sources, installation and maintenance services, and the expansion of related sectors. Increased capacity additions, technology breakthroughs, policy backing, and international partnerships define Pakistan's future for renewable energy. Pakistan is well positioned to accelerate its transition to renewable energy, reduce greenhouse gas emissions, and contribute to a sustainable and resilient energy future thanks to favourable renewable energy potential, a supportive regulatory environment, and expanding private sector participation.

CONCLUSION

In conclusion, Pakistan's renewable energy industry is expanding and changing significantly; the adoption of renewable energy sources is being fuelled by supportive policies, scientific discoveries, and rising investments. The sector has a bright future ahead of it, despite obstacles including regulatory uncertainties and insufficient funding. Sustainable development is supported by the government's commitment, promising renewable energy potential, and international partnerships. Successful case studies show the beneficial effects of renewable energy initiatives. Realizing the full potential of renewable energy in Pakistan and ensuring a sustainable and greener future would require ongoing support for solid policies, funding alternatives, and infrastructure development.

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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