Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 4, Issue 3, 2026

PAKISTAN RENEWABLE ENERGY GENERATION EVOLUTION FROM 1947 TO PRESENT

Shafique Ahmed Soomro[*1], Jawed Ali Thaheem[2], Muhammad Raza Punjwani[3], Syed Ahsan Raza[4], Adil Noor Soomro[5]

[*1,2,3,5]*Department of Electrical Engineering, Faculty of Engineering, Science and Technology (FEST) Indus University, Karachi, Pakistan*
[4]*Department of Electrical, Faculty of Engineering, Science and Technology (FEST) Indus University Karachi, Pakistan*

[*1]shafiq.soomro@indus.edu.pk, [2]jawed.thaheem@indus.edu.pk, [3]raza.punjwani@indus.edu.pk, [4]ahsan.raza@indus.edu.pk,[5]adil.noor@indus.edu.pk

DOI: http://doi.org/10.5281/zenodo.18860883

Keywords
Keywords– Renewable Energy; Pakistan Power Sector; Hydropower; Wind Energy; Solar Energy; Installed Capacity; Electricity Generation; Energy Policy; Net Metering; Sustainable Power Systems.

Article History
Received: 05 January 2026
Accepted: 18 February 2026
Published: 04 March 2026

Corresponding Author: *
Shafique Ahmed Soomro

Abstract
Since gaining independence in 1947, Pakistan has faced persistent challenges in meeting its electricity demand due to limited initial infrastructure and rapid population and economic growth. The country's renewable energy development began with hydropower, which remained the sole significant renewable source for several decades. Early installations provided minimal capacity; however, large reservoir-based projects later established hydropower as a central pillar of the national energy system. Despite this progress, increasing reliance on thermal generation led to rising fuel import dependency and long-term energy security concerns. A major shift occurred after 2015, when prolonged electricity shortages triggered accelerated investment in wind, solar, and distributed generation technologies. Policy reforms, revised renewable energy targets, and the nationwide expansion of net-metering played a critical role in this transition. By 2025, Pakistan's installed power capacity exceeded 46 GW, with hydropower contributing nearly one-third and modern renewables steadily increasing their share. Nevertheless, the exploitation of Pakistan's vast renewable potential remains constrained by financial, institutional, and transmission-related barriers. This paper critically evaluates the historical evolution, present status, and future trajectory of renewable energy in Pakistan, providing insight into the gap between policy ambitions and on-ground performance, and identifying key challenges that must be addressed to achieve sustainable and reliable power sector transformation.

1. INTRODUCTION

At the time of its independence in 1947, Pakistan inherited a limited energy infrastructure. In the early years, the country concentrated primarily on large hydroelectric projects to address the growing demand for electricity. These hydropower installations marked the beginning of Pakistan's renewable energy journey, while modern technologies such as solar and wind were not widely adopted until much later. The total installed capacity of Pakistan's renewable energy **sector was 69 MW** in the initial years, and its growth up to **46605MW 2025** is illustrated in Figure 1.

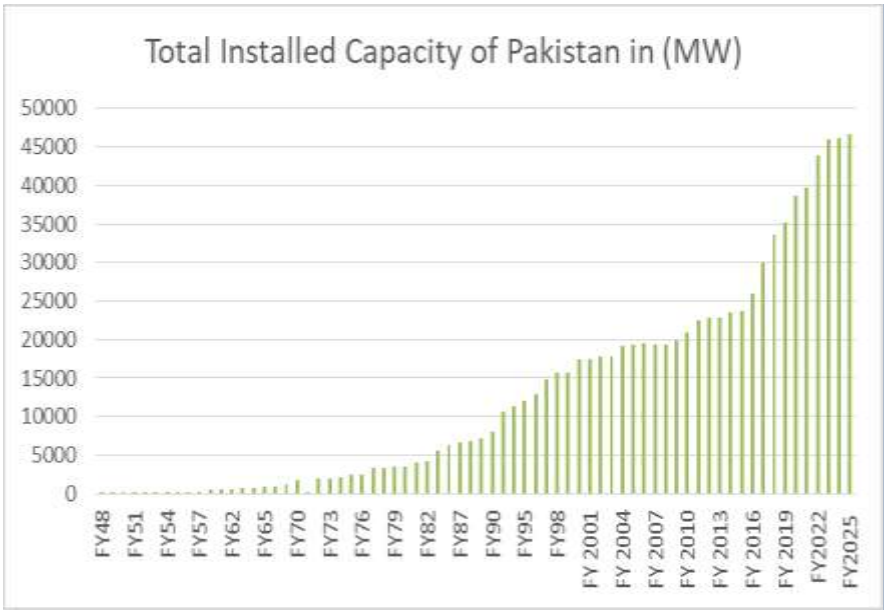

Fig. 1. Total Installed Electricity Capacity of Pakistan (1947–2025)[1].

The electricity generation in Pakistan was only **118 GWh** in the early years; however, it increased substantially over time, reaching **90,145 GWh by 2025**, as shown in **Figure 2**[1]**.**

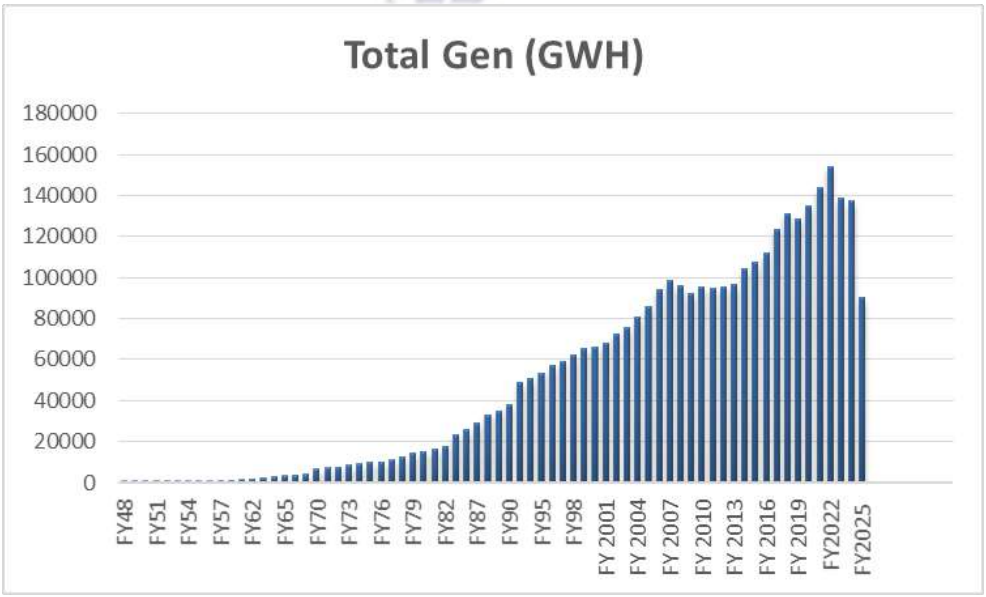

FIG. 2 . Total GENERATION Capacity of Pakistan (1947–2025)

At independence in 1947, Pakistan inherited minimal energy infrastructure from British colonial rule, leaving the new nation with severe electricity shortages and an urgent need to develop power generation capacity The country's early energy strategy centered heavily on exploiting its significant hydroelectric potential, particularly from rivers flowing from the Himalayan region Major hydropower projects became the foundation of Pakistan's renewable energy portfolio, with installations like the Warsak Dam (1960) and later the Tarbela Dam (1976) and

Mangla Dam (1967) providing substantial clean electricity generation However, Pakistan's energy mix also became increasingly dependent on thermal power plants using imported oil and later natural gas, creating long-term energy security challenges For several decades following independence, hydroelectric power remained virtually the only form of renewable energy development, while modern technologies like solar photovoltaics and wind turbines were not yet economically viable or prioritized in national energy planning.

2. HYDROPOWER PLANTS

In Pakistan's first 50 years of independence, the country effectively utilized its hydropower potential by developing major dams and power stations, with hydroelectric generation reaching its peak contribution of 70% of total electricity in 1960 [1] However, the growth of hydropower in subsequent years became marred by sociopolitical controversies, lack of consensus among federating units, and unavailability of investors to finance such projects [2]The energy policy narrative during the early decades focused primarily on water resource management, with energy concerns only being realized in the late 1960s as demand grew beyond existing capacity Pakistan conducted its first-ever energy and power planning study in 1967, marking the beginning of formal energy sector planning [2]. Despite this early planning effort, subsequent policies remained fossil-fuel-centric until 2006, reflecting the global energy paradigm of the era and Pakistan's increasing reliance on thermal power generation. By 2014, hydropower's share had declined significantly to only 30% (7000 MW), representing just 9% of overall power produced from primary sources, though it increased marginally to 31% by 2015.
Table I shows the major hydropower plants in Pakistan, including their location, type, installed capacity, and year of commissioning. It highlights the historical development of hydropower from small canal-based plants in the 1920s to large reservoir and run-of-river projects commissioned up to 2024.

TABLE.1 shows the major hydropower plants in Pakistan[1]

S/N	Hydropower Plant	Location	Type	Capacity (MW)	In-Service / Commissioning Year
1	Renala Khurd	Renala, Punjab	Run-of-Canal	1.1	1925
2	Malakand / Jabban	Malakand, KPK	Run-of-River	22	1935
3	Rasul	Mandi Bahauddin, Punjab	Run-of-Canal	22	1952
4	Dargai	Malakand, KPK	Run-of-Canal	20	1952
5	Kurram Garhi	Kurram Garhi, KPK	Run-of-Canal	4	1958
6	Chichonki Malian	Sheikhupura, Punjab	Run-of-Canal	13	1959
7	Warsak	Peshawar, KPK	Run-of-River	243	1960
8	Shadiwal	Gujrat, Punjab	Run-of-Canal	14	1961
9	Nandipur	Gujranwala, Punjab	Run-of-Canal	14	1963
10	Mangla Dam	Mirpur, Azad Kashmir	Reservoir	1,000	1967
11	Chitral	Chitral, KPK	Run-of-Canal	1	1975

12	Tarbela Dam	Tarbela, KPK	Reservoir	4,888	1977
13	Chashma	Chashma, Punjab	Run-of-River	184	2000
14	Jagran	Neelum, Azad Kashmir	Run-of-River	30	2000
15	Ghazi-Barotha	Attock, Punjab	Run-of-River	1,450	2003
16	Malakand-III	Malakand, KPK	Run-of-River/Canal	84	2008

The total electricity generated from hydropower plants in Pakistan during 2023–2024 is 40,145 GWh, contributing a significant portion of the country's overall electricity generation. From 2018 to 2024, Pakistan's hydropower installed capacity increased from **9,412 MW to 10,682 MW**, with annual electricity generation rising from **35,720 GWh to 40,145 GWh**, as shown in **Table II**.

TABLE.2 Installed Generation Capacity (MW) and Energy Generation (GWh)

DESCRIPTION	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
Hydel						
Capacity by WAPDA	9,387	9,389	9,389	9,407	9,477	9,477
Energy Generation by WAPDA	31,146	37,431	37,144	33,449	31,617	35,268
Capacity by IPPs	382	485	485	1,205	1,205	1,205
Energy Generation by IPPs	1,432	1,795	1,922	2,374	4,834	4,877
Total Hydel Capacity	**9,769**	**9,874**	**9,874**	**10,612**	**10,682**	**10,682**
Total Hydel Energy Generation	**32,578**	**39,226**	**39,066**	**35,822**	**36,452**	**40,145**

In Figure.3 Shows 2018 TO 2024 Data of installed capacity of Pakistan Hydro, NTDC and Other renewable and nonrenewable power plants. In 2024, approximately 26.98% of the installed capacity was contributed by hydropower, while other renewable sources accounted for about 7.23%, including IPPs, other non-renewable sources, K-Electric, and imported power. In 2024, approximately 26.98% of the installed capacity was contributed by hydropower, while other renewable sources accounted for about 7.23%, including IPPs, other non-renewable sources, K-Electric, and imported power.

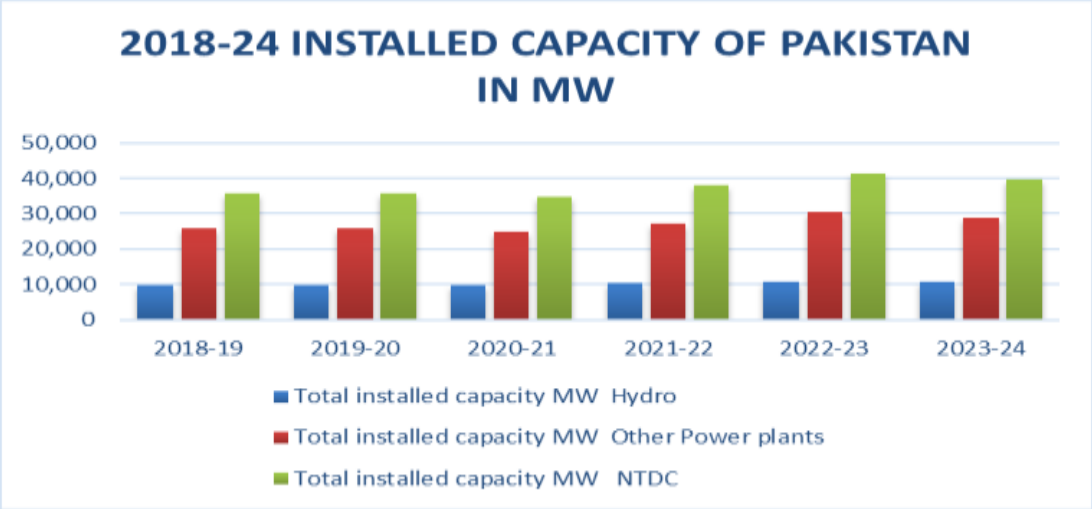

Fig. 3. Hydro and other Installed Electricity Capacity of Pakistan

In 1948 only 11mw installed capacity of Pakistan that time 15.94% only and in 2024 is 27.41% approximately

3. WIND POWER PLANTS

Since 2015, Pakistan has significantly accelerated the deployment of modern renewable energy technologies. Wind power capacity has surpassed 1,000 MW, while solar installations exceeded 400 MW by 2018. The government has increased renewable energy targets to 20% by 2025 and 30% by 2030, alongside nationwide expansion of net-metering. These initiatives have helped mitigate severe energy shortages that once resulted in 14–18 hours of daily load-shedding.

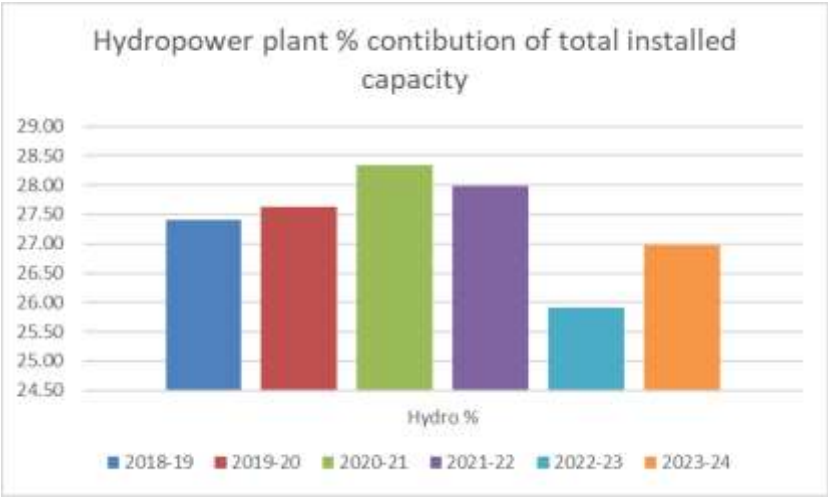

Fig. 4. 2018 -2024 installed capacity of Hydro power plants

The period from 2015 onwards marked a dramatic acceleration in Pakistan's renewable energy deployment, driven by severe energy shortages that caused 14-18 hours of daily load-shedding across the country [2].By 2015-2016, Pakistan was generating 553.3 MW of electricity through

modern renewable energy technologies connected to the national grid[2].The government significantly raised its renewable energy ambitions, setting new targets of achieving 20% and 30% of generation capacity through alternative and renewable energy technologies by 2025 and 2030 respectively, up from the previous modest target of 5% by 2030 [3].

Wind power emerged as a major success story during this period, with the first commercial wind project installed by Fauji Fertilizer Company Energy Limited (FFC) at 50 MW capacity in 2013, followed by rapid expansion. By 2018, eighteen wind power projects with a cumulative capacity of 1006 MW were supplying electricity to the national grid, primarily located in the wind corridors of Jhimpir and Gharo-Keti Bandar in Sindh Province [4]

Solar energy development accelerated significantly with the launch of the Quaid-e-Azam Solar Park (QASP) in 2015-16, which began operations with 100 MW capacity producing 25 GWh [6] By 2018, five solar energy projects totaling 430 MW capacity had become operational, with solar energy production reaching 768 GWh and showing consistent year-over-year growth [5].

The net-metering program expanded dramatically from its initial implementation, growing from coverage in a few cities in 2015 to nationwide availability by 2017[3]. By the end of 2019, approximately 1,150 net-metered distributed generation systems with a total capacity of 19.55 MW had been installed, including notable installations at Parliament House (1 MW) and government buildings Pakistan set ambitious net-metering targets of 1 GW by 2020-21 and 4.5 GW by 2025 [4], [6].

Over the past decade, Pakistan has demonstrated notable progress in embracing renewable energy sources through government-led initiatives that offer incentives for private-sector investment, stimulating the establishment of numerous solar and wind farms nationwide [7]. The country also continued developing biomass capacity, with approximately six sugar mills generating 201 MW from bagasse becoming operational [8].

4. Current Status and Capacity by Technology

Comparison of sources

A. Installed capacity mw

In early year only 69mw installed capacity in which only non renewable power plant is hydro power plant is 11% from 69 % shown in figure 5 And 1948 till 2020 data shows in figure .6

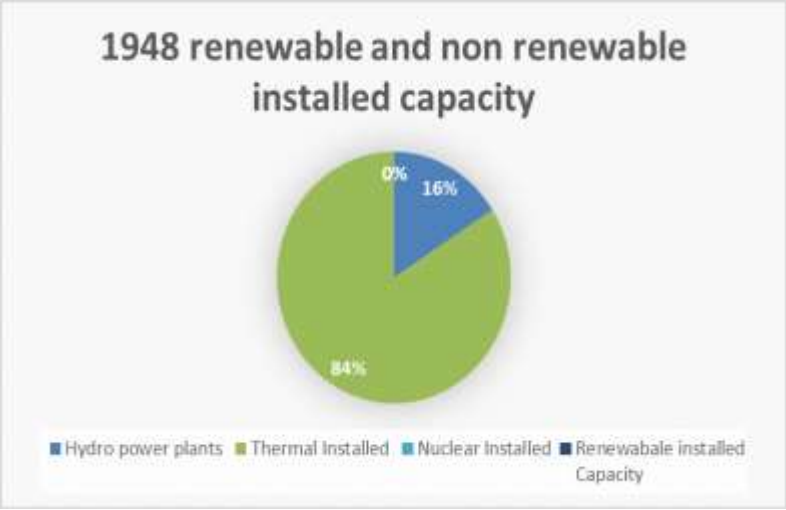

Fig. 5. 1948 installed capacity of power plants

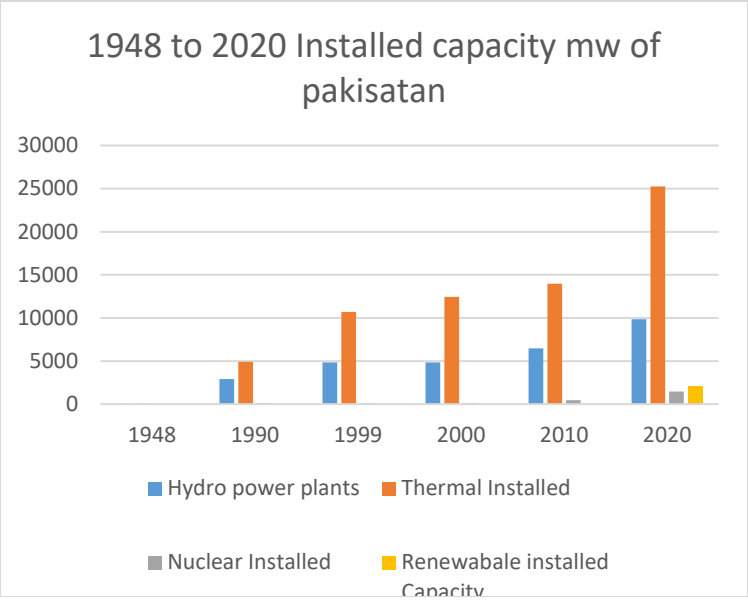

Fig. 6. 2018 -2020 installed capacity of Hydro power plants

2018 to 2024 installed capacity of Pakistan in different sources shown in Table

TABLE.3 Installed Generation Capacity (MW)

DESCRIPTION	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
Hydro power plant						
Capacity by WAPDA	9,387	9,389	9,389	9,407	9,477	9,477
Capacity by IPPs	382	485	485	1,205	1,205	1,205
Total Hydel Capacity	**9,769**	**9,874**	**9,874**	**10,612**	**10,682**	**10,682**
Thermal						
Installed Capacity by GENCOs	5747	5747	3851	3707	3707	3707
Installed Capacity by IPPs	16776	16776	16679	17340	20570	18798
Total Thermal Installed Capacity	**22523**	**22523**	**20530**	**21047**	**24277**	**22505**
Nuclear						
Installed Capacity	**1345**	**1345**	**2445**	**3545**	**3545**	**3545**
Renewable						
Solar Installed Capacity	400	400	400	500	500	650
Wind Installed Capacity	1,235	1,235	1,235	1,845	1,845	1,845
Bagasses Installed Capacity	364	364	364	364	364	364
Energy Import from KE	44	41	13	6	4	11
Total Installed Capacity	35,636	35,741	34,848	37,913	41,213	39,591

B. **Energy Generation Capacity GWh**

Pakistan currently has about 127,420GW of installed electricity generation capacity, approximately with a shifting mix toward cleaner energy (hydro, nuclear, solar, wind), though thermal remains the largest component. Electricity generation in FY2023-2024 also reflected rising contributions from these cleaner sources. Shown in table 4 and contribution in percentage is shown in figure.7

TABLE.4 2023-2024 Generation Capacity (MWh)

Source	Energy Generation (GWh)
Hydro Public	35268
Hydro IPPs	4877
Thermal Public	3563
Thermal IPPs	54507
Solar IPPs	975
Wind IPPs	3940
Nuclear IPPs	23201
Bagasse IPPs	1078
Import from KE	11

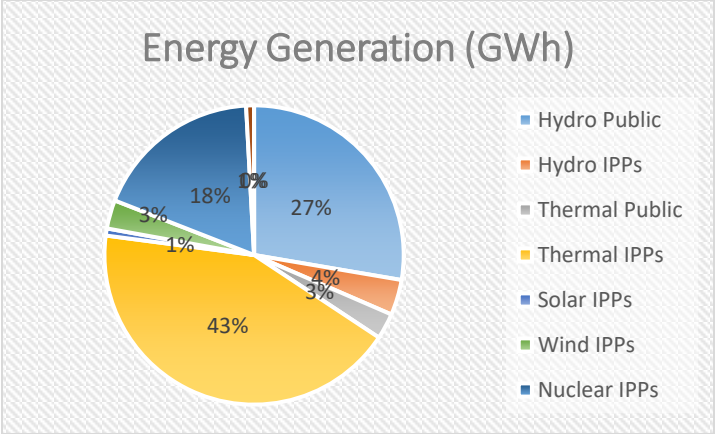

Fig. 7. 2024Geneartion capacity of 2024

Table 5 Shows Renewable Capacity of Pakistan

No.	Power Plant	Type	Location	Capacity (MW)
1	Tarbela Hydropower Station	Hydropower	KP / Punjab	3,478
2	Mangla Hydropower Station	Hydropower	Punjab	1,150
3	Ghazi–Barotha	Hydropower	Punjab	1,450
4	Neelum–Jhelum	Hydropower	AJK	969
5	Suki Kinari	Hydropower	KP	884
6	Karot	Hydropower	Punjab	720
7	Warsak	Hydropower	KP	243
8	Gomal Zam	Hydropower	KP	17.4
9	Dargai	Hydropower	KP	20
10	Renala Khurd	Hydropower	Punjab	1.1
11	Other small & canal hydel plants	Hydropower	Punjab / KP	~2,500

12	Quaid-e-Azam Solar Park (operational)	Solar	Bahawalpur	400
13	Appolo Solar	Solar	Bahawalpur	100
14	Best Green Energy	Solar	Bahawalpur	100
15	Crest Energy Solar	Solar	Bahawalpur	100
16	Atlas Solar	Solar	Layyah	100
17	Oursun Solar	Solar	Thatta	50
18	Gharo Solar	Solar	Thatta	50
19	Harappa Solar	Solar	Sahiwal	18
20	Rooftop / Net-metering Solar	Solar	Nationwide	~2,500
21	AJ Power Solar	Solar	Khushab	12
22	Zorlu Wind Power	Wind	Thatta	56.4
23	FFC Energy Wind Farm	Wind	Jhimpir	49.5
24	Sachal Wind Power	Wind	Jhimpir	49.5
25	Three Gorges Wind	Wind	Jhimpir	49.5
26	Foundation Wind Energy-I	Wind	Gharo	50
27	Foundation Wind Energy-II	Wind	Gharo	50
28	Yunus Energy Wind	Wind	Jhimpir	99
29	Sapphire Wind Power	Wind	Jhimpir	52.8
30	Metro Power Wind	Wind	Jhimpir	50
31	Master Wind Energy	Wind	Jhimpir	52.8
32	Other operational wind farms	Wind	Sindh	~1,200
33	Bagasse cogeneration plants (sugar mills)	Biomass	Punjab & Sindh	~250

5. Current Status and Capacity by Technology

In 2024, Pakistan's aggregate power generation capacity stands at roughly **39,000 MW**. Despite this capacity, renewable energy sources contribute a relatively small share, accounting for just **3–5%** of the total electricity generated. Hydropower remains a dominant component of the energy mix,

providing **9.8 GW** (approximately 30%). Among modern renewable technologies, wind energy leads with over **3,200 MW** generated across 45 projects, significantly outpacing solar capacity, which currently sits between **430 and 530 MW**. Pakistan possesses massive untapped renewable energy potential, with estimates indicating capacity for 1,600 GW through solar energy projects, up to 44,000 MW through wind power,[7,12] 13,900 GWh through biomass, 100,000 MW through geothermal resources, and 100 GW through small hydropower projects. However, despite this enormous potential, many ongoing renewable energy projects are not generating their expected results, with a long list of projects recently abandoned or delayed due to poor operational performance The failure of renewable energy projects to meet planned operational performance stems from multiple systemic challenges that are distinct from those faced by other countries, including lack of data and transparency, an unstable economy, corruption, political instability, financial constraints, and socio-cultural challenges [7].These issues have severely hampered the translation of Pakistan's substantial renewable energy potential into actual electricity generation. The disconnect between ambitious targets and reality is evident in Pakistan's continued energy crisis. While the government predicted in 2018 that Pakistan would achieve energy surplus of 2,732 MW by 2019, the country still faces an energy shortfall of 3,000 MW due to transmission losses and other systemic inefficiencies .This persistent energy deficit has meant that load-shedding of 14-18 hours daily, which began in 2011, has continued well beyond government projections for its resolution [4].

The scale of underperformance becomes clear when considering that Pakistan generated only 553.3 MW through modern renewable energy technologies connected to the national grid in 2015-2016, a fraction of the country's theoretical potential . While hydropower maintains a relatively high share compared to other modern renewable technologies, the overall renewable energy sector continues to struggle with implementation challenges that prevent Pakistan from capitalizing on its substantial natural advantages [4].

6. Conclusion

This study presented a comprehensive assessment of the evolution, current status, and future prospects of renewable energy development in Pakistan. Beginning with a severely constrained power system at independence, Pakistan's renewable energy journey has been historically dominated by hydropower, which remains the backbone of clean electricity generation. Large-scale hydropower projects significantly enhanced national capacity; however, over time, increased reliance on fossil-fuel-based thermal generation reduced the share of renewables and introduced long-term energy security and economic challenges.

The analysis shows that policy reforms introduced after 2015 marked a turning point, enabling rapid growth in modern renewable technologies such as wind, solar, and distributed generation through net-metering. By 2024–2025, Pakistan achieved notable expansion in installed capacity, particularly in hydropower and wind energy, contributing to improved supply stability and reduced load-shedding. Nevertheless, despite possessing vast untapped renewable potential, the actual contribution of renewables—excluding hydropower—remains limited.

Persistent structural barriers, including inadequate transmission infrastructure, financial constraints, policy inconsistency, governance challenges, and data transparency issues, continue to hinder large-scale renewable deployment. The findings indicate a clear gap between Pakistan's ambitious renewable energy targets and real-world implementation. Addressing these challenges through coordinated policy execution, grid modernization, investment facilitation, and institutional reforms is essential for achieving the national targets of 25% renewable energy by 2025 and 30% by 2030. Strengthening these areas will be critical for ensuring a sustainable, resilient, and economically viable power sector for Pakistan's future.

7. Future and Target Goals

The government of Pakistan has established new, ambitious targets for renewable energy integration. The updated policy calls for renewable sources to constitute 25% of the total energy mix by 2025, increasing to 30% by 2030. This represents a substantial upward revision from the previous goal of 5% by 2030. In line with the "Pakistan Vision 2030," there will be an emphasized and accelerated development of wind, hydropower, and solar power infrastructure. The plan also specifies net-metering capacity targets of 1 gigawatt (GW) by 2020-21 and 4.5 GW by 2025. Pakistan has dramatically revised its renewable energy ambitions upward in recent years, setting targets to achieve 25% renewable power generation by 2025 and 30% by the end of this decade [9]. These targets represent a substantial increase from the country's previous modest goal of achieving only 5% renewable energy share in total generation by 2030 [10]. The government's comprehensive framework for achieving these goals is outlined in Pakistan Vision 2030, which specifically focuses on accelerating the development of renewable energy power represented by wind power, hydropower, and photovoltaics. This strategic plan emphasizes the construction of small hydropower projects not exceeding 50,000 kilowatts, along with expanded wind power and solar power plants to meet the rapid growth of electricity demand driven by economic development [11].

Pakistan has also established specific targets for distributed generation through its net-metering program, aiming to achieve 1 GW of net-metered installed capacity by 2020-21 and 4.5 GW by 2025[4] . This represents a significant scaling up from the 398 MW of distributed solar capacity installed through March 2022[10].

The government recognizes Pakistan's enormous solar energy potential of up to 100,000 MW, which provides the technical foundation for these ambitious renewable energy targets[11]. However, achieving these goals will require overcoming the systemic challenges that have historically prevented Pakistan from translating its substantial renewable energy potential into actual deployment at scale.

References

[1] 'https://www.ntdc.gov.pk/energy'.

[2] 'Tareen, W. U. K., Anjum, Z., Yasin, N., Siddiqui, L., Farhat, I., Malik, S. A., ... & Chek, L. W. (2018). The prospective non-conventional alternate and renewable energy sources in Pakistan—A focus on biomass energy for power generation, transportation, a'.

[3] 'Rehman, W.U., Bhatti, A.R., Awan, A.B., Sajjad, I.A., Khan, A.A., Bo, R., Haroon, S.S., Amin, S., Tlili, I., & Oboreh-Snapps, O. (2020). The Penetration of Renewable and Sustainable Energy in Asia: A State-of-the-Art Review on Net-Metering. IEEE Access, 8'.

[4] '4. Uddin, R., Raza Khan, H., Arfeen, A., Shirazi, M.A., Rashid, A., & Shahbaz Khan, U. (2021). Energy Storage for Energy Security and Reliability through Renewable Energy Technologies: A New Paradigm for Energy Policies in Turkey and Pakistan. Sustainabil'.

[5] 'Ul-Haq, A., Jalal, M., Sindi, H.F., & Ahmad, S. (2020). Energy Scenario in South Asia: Analytical Assessment and Policy Implications. IEEE Access, 8, 156190-156207'.

[6] 'Huo, W., Zulfiqar, M., Parveen, S., Ullah, M.R., & Chand, A. (2023). Increasing ecological sustainability using the combinations of technologies to produce power. Heliyon, 9.'.

[7] 'Maqbool, R., Deng, X., & Rashid, Y. (2020). Stakeholders' satisfa[1] 'Latif, K., Raza, M.Y., Chaudhary, G.M., & Arshad, A. (2020). Analysis of Energy Crisis, Energy Security and Potential of Renewable Energy: Evidence from Pakistan. Journal of Accounting '.

[8] 'Latif, K., Raza, M.Y., Chaudhary, G.M., & Arshad, A. (2020). Analysis of Energy Crisis, Energy Security and Potential of Renewable Energy: Evidence from Pakistan. Journal of Accounting and Finance, 6, 167-182'.

[9] 'Naeem, M.H., & Riaz, L. (2022). Renewable Energy-Based Distributed Generation in Pakistan. Policy Perspectives.'.

[10] 'Mahmood, A., Wang, X., Shahzad, A.N., Fiaz, S., Ali, H., Naqve, M., Javaid, M.M., Mumtaz, S., Naseer, M., & Dong, R. (2021). Perspectives on Bioenergy Feedstock Development in Pakistan: Challenges and Opportunities. Sustainability'.

[11] 'Han, M., Tang, J., Lashari, A.K., Abbas, K., Liu, H., & Liu, W. (2022). Unveiling China's Overseas Photovoltaic Power Stations in Pakistan under Low-Carbon Transition. Land.'.

[12] Soomro, S. A., & Faisal, M. Wind Energy Status and Potential Assessment across Coastal Mega City, of Pakistan.