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Hybrid Energy Sources and Pakistan's Energy Crisis: Opportunities and Challenges for Climate and Energy Sustainability

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Abstract

An energy transition is a prerequisite and considered of paramount significance to meet the goal of climate and energy security sustainability. This transition is hardly conceivable without acknowledging the massive worldwide potential of renewable energy. Power outage in Pakistan that is caused primarily by insufficient and expensive power generation, line losses, and ineffective planning has escalated Pakistan's energy crisis. Almost every single sector of national economy has been adversely affected because of this excessive power outage. Recent floods in Pakistan, one of the outcomes of climate change, have necessitated incorporation of clean energy fuels to ensure climate sustainability. Keeping the magnanimity of the crisis in consideration, Islamabad has adopted some remedial measures to overcome this energy crisis but the problem still persists and requires pragmatic policies. The under-utilized renewable potential and power generation by expensive imported fossil fuels has led to excessive increase in cost of energy generation and climate deterioration. However, it is imperative for the government to adopt appropriate and workable solutions to address the energy crisis adequately. This is a qualitative study that employs content analysis technique to explore the dynamics of Pakistan's energy security and climate sustainability in a substantive manner. This paper is aimed at exploring the inherent potential of Pakistan in renewable energy (RE) not only to mitigate Pakistan's energy crisis but also to ensure sustainability in climate and energy security. Moreover, this study presents critical evaluation of the appropriate sites of wind and solar power plants in Pakistan. Last but not the least, it proposes short and long term remedial measures to mitigate if not to overcome this energy crisis entirely.

Keywords: energy transition; renewable energy; power outage; energy crisis; remedial measures; Pakistan.

Introduction

In this era of globalization and huge breakthroughs in scientific developments, research advancements and particularly their practical

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applications are taken into account.[1] In order to keep industries alive and economies moving, energy has become a fundamental necessity. The fact that conventional energy sources for the creation of electricity are becoming less abundant over time must be taken into account in this situation since they may exacerbate global warming, which is hazardous to the environment.[2] Huge efforts are being made to minimize the production of energy using natural gas, petroleum products, and coal because they are harmful to the environmental sustainability.[3]

In light of this, both industrialized and developing nations are observing nuclear energy as a suitable substitute for fossil fuels. But, as it is not available to most of the countries in the world due to its high costs, environmental risks, technical issues, limited supply, and other problems it is, perhaps, not a reasonable substitute for fossil fuels. Other unconventional sources of energy are deemed as appropriate alternate of fossil fuels in the long-run.[4'5] As a corollary, this cogent vision for avoiding health risks, its commitment to environmental sustainability, and its maintenance of a clean environment are well regarded.[6] The biggest markets in Asia will refer to Renewable Energy (RE) as the best alternative in the next 10 years as a result of growing awareness of the benefits of solar and wind energy. According to the expected calculations, up until

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1 M. Mujahid Rafique and S. Rehman, 'National Energy Scenario of Pakistan – Current Status, Future Alternatives, and Institutional Infrastructure: An Overview,' *Renewable and Sustainable Energy Reviews* 69 (2017), 156-67.

2 Hafiz Bilal Khalil and Syed Jawad Hussain Zaidi, 'Energy Crisis and Potential of Solar Energy in Pakistan', *Renewable and Sustainable Energy Reviews* 31 (2014), 194-201.

3 Zeeshan Alam Nayyar, Nayyer Alam Zaigham, and Abdul Qadeer, 'Assessment of Present Conventional and Non-Conventional Energy Scenario of Pakistan', *Renewable and Sustainable Energy Reviews* 31 (2014): 543-553.

4 Harry Lehmann, 'Overall Energy Policy and the Advantages of Renewable Energy Technologies', *Wuppertal Institute for Climate, Energy, and Environment*, (1995): 1-32.

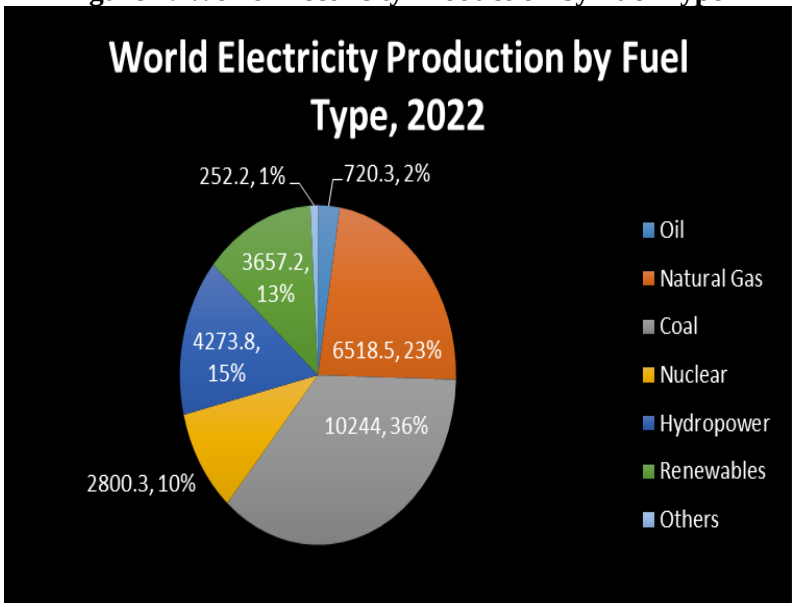
5 Christopher Flavin and Nicholas K. Lenssen, *Power Surge: Guide to the Coming Energy Revolution* (New York: W.W. Norton, 1994).

6 Joshua S. Hill, 'Clean Power: Solar and Wind will Prove Cheapest form of Electricity in the Future', *Clean Technica*, 10 February 2015, https://cleantechnica.com/2015/02/10/solar-wind-will-prove-cheapest-form-electricity-future/

the F.Y. 2030, over 1/5th of global energy will come from sources that generate wind energy.[7]

This promotes wind as one of the safest sources of RE with both environmental and financial benefits. Presently, electricity is the most widely used source of energy for boosting industrial production. The four components of today's electric power systems are generation, transmission, distribution, and consumption. The majority of powers producing units are frequently located in remote locations, where electricity is produced, sent over great distances to urban areas via transmission network, and then distributed using distribution lines. Due to the important role that electricity renders in modern society, all available options for producing electricity are carefully considered. Looking at the global electricity generation, it was 28466.3 TWh by the end of 2021[8] while the contribution of oil, natural gas, coal, nuclear, hydropower, renewables, and others is shown in the figure 1.

Figure 1: World Electricity Production by Fuel Type[9]



7 'Renewables 2022 Global Status Report', REN21, accessed September 15, 2023, https://www.ren21.net/gsr-2022/

8 'Statistical Review of World Energy 2022', British Petroleum (BP), accessed 20 September 2023, https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

9 'Statistical Review of World Energy 2022', British Petroleum.

This study concentrates on Pakistan's power sector, including its influence, current needs, issues, and potential remedies. Although it is enriched with plenty of energy resources, its energy crisis is stemmed from the non-utilization of the available energy potential, inconsistency and unfocussed attention towards addressing the energy issues, and lack of constructive policy and planning among others. Resultantly, around 220 million people, an approximate population of Pakistan, are currently suffering from power outage crisis in Pakistan.[10'11'12] To address the issue of electricity shortages, some of the ferocious public rallies have also been witnessed in many Pakistani cities. As a short-term measure, furnace oil is consumed for the generation of electricity on an extensive scale. Owing to the frequent variations in furnace oil prices, the electricity cost went up manifolds in the country and it became an uphill task for the government to stabilize electricity prices. Consequently, the affordability of electricity which is a basic necessity of people has become a major concern for many in the country.[13] Pakistan bears a heavy financial burden as a result of its reliance on furnace oil for the production of power. However, Pakistan continues to have a serious energy shortage. To address this vital issue, considerable efforts are needed.

Being a Pakistani citizen, the author can attest that during the summer the country's urban areas experience an increase in electricity outages of 8 to 10 hours, while rural areas experience outages of 12 to 14 hours. During the winter, outages range from 4-6 hours in cities to 6-8 hours in villages[14]. The current energy crisis in Pakistan has mandated that the country's energy policies should undergo a massive change. Investing in Renewable Energy (RE) producing technologies, however, is an appropriate way to reduce reliance on furnace oil. To meet the demand for everyday electricity consumption, many nations have successfully

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10 'Pakistan: Total Population from 2018-2028', *Statista*, accessed 25 September 2023, https://www.statista.com/statistics/383245/total-population-of-pakistan/

11 'Protests against Power Outages Turn Violent', *Dawn*, 20 June 2015, https://www.dawn.com/news/1189268

12 'Pakistan Switched to Furnace Oil for Power Production in December', *The Express Tribune*, 23 January 2017, https://tribune.com.pk/story/1304687/expensive-source-pakistan-switched-furnace-oil-power-production-december

13 *Ibid*.

14 *Dawn*, 20 June 2015.

established their RE generation plants.[15'16] A variety of methods for producing RE have been developed, presented in illustrations and publications along with descriptions of potential solutions to the energy shortage.[17'18'19'20'21'22'23] As a result, a thorough examination of all the data and an elaborated plan for resolving the energy issues are presented in this study.

Power Sector Structure of Pakistan

Fundamentally, the structure of energy sector involves various processes from its generation to supply and then consumption by the consumers. Nonetheless, it is also quite complicated as it involves multiple organizations and multitude of processes. The comprehensive mechanization of this sector is pictorially presented in figure 2 below:

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15 S.K. Singal, 'Review of Augmentation of Energy Needs Using Renewable Energy Sources in India', *Renewable and Sustainable Energy Reviews*, 11:7 (2007), 1607-15.

16 Tom Bond and Michael R. Templeton, 'History and Future of Domestic Biogas Plants in the Developing World', *Energy for Sustainable Development*, 15:4 (2011), 347-54.

17 Syeda Shaima Meryem, Sheikh Saeed Ahmad, and Neelam Aziz, 'Evaluation of Biomass Potential for Renewable Energy in Pakistan Using LEAP Model', *Inter. Jour. Emerg. Trends Eng. Development*, 1:3 (2013), 243-249.

18 Hadeed Ahmed Sher, Ali F. Murtaza, Khaled E. Addoweesh, and Chiaberge Marcello, 'Pakistan's Progress in Solar PV Based Energy Generation', *Renewable and Sustainable Energy Reviews* 47 (2015), 213-17.

19 Umar K. Mirza, Nasir Ahmad, and Tariq Majeed, 'An Overview of Biomass Energy Utilization in Pakistan', *Renew. Sustain. Energy Rev.* 12:7 (2008), 1988-96.

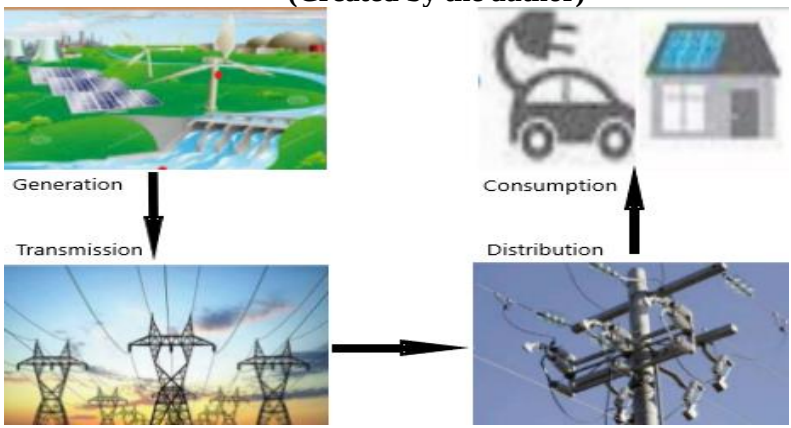
20 Mukhtar H. Sahir, and Arshad H. Qureshi, 'Assessment of New and Renewable Energy Resources Potential and Identification of Barriers to Their Significant Utilization in Pakistan', *Renew. Sustain. Energy Rev.* 12:1 (2008), 290-98.

21 M. Chaudhry, Raza Ashraf, and S.A. Hayat, 'Renewable Energy Technologies in Pakistan: Prospects and Challenges', *Renew. Sustain. Energy Rev.* 13:6 (2009), 1657-62.

22 M. Kamran, 'Current Status and Future Success of Renewable Energy in Pakistan', *Renew. Sustain. Energy Rev.* 82 (2018), 609-17.

23 S.S. Amjid, M.Q. Bilal, M.S. Nazir, and A. Hussain, 'Biogas, Renewable Energy Resource for Pakistan', *Renew. Sustain. Energy Rev.* 15:6 (2011), 2833-37.

Figure 2: Basic Model of Power Sector Structure (Created by the author)



Pakistan's power sector is comprised of various institutions. These institutions are tasked to perform different functions including tariff regulations, power production and supply estimation, electric system's maintenance, and facilitation of citizens etc. The various institutions in the power sector are responsible for power production, its transmission, distribution and utilization. Some of these major institutions and their functions are explained below:

Ministry of Water and Power

The supreme and the most prominent body in the hierarchy of institutions that is tasked not only with generation but also with transmission and distribution of power is 'Ministry of Water and Power'. This ministry performs several tasks including maintaining the balance in demand and supply, providing conducive environment for investors, and employment of new strategies for the development of energy industry etc.

National Electric Power Regulation Authority (NEPRA)

The NEPRA was established back in 1997 with the prime objective of regulating the supply of power to the masses.[24] This institution is authorized to issue permit for investments, licensing, and tariff balancing both in bulk and retail for maintaining the profit/loss equation. Moreover,

[24] 'National Electric Power Regulatory Authority (NEPRA)', accessed on 10 October 2023, https://www.nepra.org.pk/

it is also tasked with framing tariff policies and implementation of adequate standards for energy supplies to make sure of people safety.[25]

Private Power Infrastructure Board (PPIB)

This institution is primarily accountable for undertaking energy projects in private power production industry. One of the most common projects upheld by PPIB are IPPs and small hydropower projects of at least 50 MW capacity. Moreover, this body is well represented from all the governing entities of Pakistan including AJK.[26]

Provincial and AJK Organizations

Several entities have been established to ensure water and power supplies to the masses. All the provincial governments took steps to establish these organizations to make sure of adequate supplies of water and power to the people. For this very objective, authorities in power and irrigation departments are operating in all the provinces except KPK. However, department was established in KPK with the name of 'Sarhad Hydro Development Organization' (SHYDO) which was later renamed as 'Pakhtunkhwa Energy Development Organization' back in 2013. To install and maintain units having maximum of 50 MW capacity is another key responsibility of these organizations.[27]

Power Pragmatisms

To unify all the small regulatory and distributary organization and authorities responsible for generation and supply of water and electricity since 1947, the 'Water and Power Development Authority' (WAPDA) was established under WAPDA Act in 1958. One of its key objectives was to keep an eye on the power projects in the country for maintaining standards of electricity in Pakistan.

Power Generation Networks

Pakistan, owing to its geographical location and diversity in natural resource wealth, can utilize diverse sources for power production. All the major sources from which electricity is produced in Pakistan include coal, oil, gas, nuclear, hydel, solar, wind, tidal, and geothermal etc. Moreover,

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25 Ibid.,

26 'Private Power Infrastructure Board (PPIB)', Ministry of Energy (Power Division), accessed on 15 October 2023, https://www.ppib.gov.pk/.

27 'Sarhad Hydel Development Organization Service Rules 1995', Khyber Pakhtunkhwa Code, accessed on 12 October 2023, https://kpcode.kp.gov.pk/homepage/RuleDetails/1047

'Generation Companies' (GENCOs) are further categorized into conventional and non-conventional. The key function of electricity production is primarily performed and controlled by these GENCOs. The table below enlists three important GENCOs that operate in Pakistan:

Table 1: Major power generation companies of Pakistan[28]

S. No.	Name of the Company	Operations
1	Southern Generation Power Company Limited (GENCO-I)	Jamshoro, Sindh
2	Central Generation Power Company Limited (GENCO-II)	Jacobabad, Sindh
3	Northern Generation Power Company Limited (GENCO-III)	Lahore, Punjab

Transmission Networks

The second fundamental ingredient of power sector structure is the transmission system. In order to execute transmission of electricity from its source of generation to the consumer in distant areas, plenty of grid stations have been established and huge network of transmission lines has been stretched throughout the country. 'The National Transmission and Distribution Company' (NTDC) is established to perform these functions.[29] NTDC maintains a length of 7359 km of 220 KVs and 5077 km of 500 KVs transmission lines.[30] Table 2 provides the details of grid stations and their location that operates under NTDC.

Table 2: Electricity transmission network in Pakistan[31]

S. No.	Grid Station Capacity	Islamabad	Lahore	Multan	Hyderabad	Total
1	220 KV	07	16	05	09	37
2	500 KV	02	03	04	04	13

28 'National Electric Power Regulatory Authority', accessed on 10 October, 2023, https://www.nepra.org.pk/.

29 'National Transmission and Dispatch Company Limited', accessed on 22 September 2023, https://ntdc.gov.pk/

30 *Ibid*.

31 *Ibid*.

Distribution Networks

Once the generation and transmission of electricity is done, the next step involves the distribution system. In order to provide maximum number of electricity consumers throughout the country with electricity, a broader network of 'Distribution Companies' (DISCOs) is necessarily required. For this very purpose, a huge network of distribution companies is operating in Pakistan and they are labeled as DISCOs.[32] Table 3 below enlists various sub-branches of DISCOs except for KESC:

Table 3: Sub-branches of DISCOs[33]

S. No.	Companies Controlled by Regional Control Center (RCC) Jamshoro	Companies Controlled by National Power Control Center (NPCC) Islamabad
1	SEPCO	TESCO
2	QESCO	IESCO
3	HESCO	GEPCO
4		LESCO
5		FESCO
6		MEPCO
7		PESCO

Water and Power Regulation Authority is authorized to manage electricity GTD. Through WAPDA Act 1981, 8 'Regional Electricity Boards' (REB) were established to enhance the control of governments at provincial level. To make the distribution network more efficient, power plan initiatives were taken back in 1994 which segregated WAPDA into 14 companies. These companies were comprised of GENCOs, NTDC, and DISCOs.

Energy Profile of Pakistan

The Government of Pakistan (GoP) has put forth various plans to bolster the nation's power grid and economy. These efforts have taken shape in various policies, including the 'National Power Policy of 2013', the 'Power Generation Policy of 2015', and the 'Alternative and Renewable Energy Policy of 2019'. The overarching goal of these policies is to establish a reliable and cost-effective system for power GTD that can fulfill the energy requirements of the population, while also spurring

32 Ministry of Energy (Power Division), *Distribution Companies*, accessed on 11 August 2023, https://power.gov.pk/Detail/YThmNWQ5OGQtZGY5NC00NDk0LTgzN2MtZThhZTEzMTY5NTg2

33 *Ibid*.

economic growth. The National Power Policy of 2013, for instance, sought to eliminate power outage, cost-affectivity of electricity, minimize transmission and distribution losses, increase revenue, and streamline decision-making processes at ministerial level and other relevant institutions. By implementing these policies, the Pakistani Government aims to create a sustainable and stable power system that benefits all citizens and stimulates the nation's economy.

The government enacted the 'Power Generation Policy 2015' with the objective to ensure that the country had sufficient power generation capacity at the lowest possible cost, while prioritizing the use of local resources, and protecting the atmosphere from hazardous materials. The GoP introduced 'Alternative and Renewable Energy Policy 2019' not only to encourage the initiatives in renewable energy but also to support and facilitate such initiatives in the country.

The energy sector of Pakistan is susceptible to various obstacles. For example, its circular debt has been anticipated for quite some time. Islamabad has worked diligently to reduce it, but the problem has remained largely uncontrolled. Statistics show that it was approximately 450 billion rupees in 2013 and by 2018 it had risen to 1,148 billion rupees. In March 2022, it amounted to Rs 2,467 billion.[34] This indicates that it accounts for 3.8% of Pakistan's gross domestic product and 5.6% of Pakistan's government debt. It is estimated that if it continues to develop at its present rate and is not addressed, it will reach Rs 4 trillion by 2025, necessitating reforms in the power sector.

Pakistan's Energy Mix

Pakistan's oil production is insufficient to satisfy the nation's overall demand. Technological, technical, and financial limitations limit the indigenous hydrocarbon production. Resultantly, required energy demands are met by energy imports. The oil import bill was almost doubled to US$17.03 billion in 2022, compared to US$8.69 billion in 2021. The spike in energy prices globally and the enormous depreciation in the value of Pakistani currency have made energy more expensive, causing pressure on the country's external sector and widening its trade deficit. Imports of energy items increased in value by 121.15 percent and in quantity by 24.18 percent, resulting in an increase in the oil import bill of 121.15 percent.[35] The value and quantity of crude oil imports increased

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34 'Government of Pakistan (GoP)', *Pakistan Economic Survey 2021-22*, accessed on 24 September 2023, https://www.finance.gov.pk/survey/chapter_22/Highlights.pdf.

35 *Ibid*.

by 75.34 percent and 1.4%, respectively, while LNG increased by 82.90 percent and LPG imports increased by 39.86 percent.[36]

Due to a substantial increase in gas demand, the remaining natural gas reserves are rapidly depleting. The GoP looks for both short and long-term alternative remedial measures to effectively meet the nation's demands of energy. Keeping in mind this increasing demand, the GoP is concentrating on the development of new exploratory wells to maximize the national gas supplies. Additionally, both LNG and LPG are being imported to make up the deficiency in natural gas reserves. In FY2021, approximately 373 million MMBTU of LNG gas valued at approximately $3.4 billion was received from other countries. This represents approximately 30% of the nation's overall natural gas consumption. In FY2022, 75.64 percent of petrol is produced domestically, while the remaining was imported.[37]

Pakistan relies on coal as a source of electricity, with Thar being the largest provider of coal in the country. Over the past few years, Thar's reserves have been actively mined, leading to the creation of the first 660 MW Thar facility, which began operating in early fiscal year 2020. As of now, Pakistan generates a total of 5,280 megawatts using coal, with Thar contribution of 1,320 MW while the rest is contributed by imports of coal, making up about 75% of electricity being generated by coal. Although the current capacity of electricity being generated is mainly reliant on imported coal, it is expected to transform in the coming years as more Thar field-based units are incorporated.

Pakistan's potential in hydropower is abundant and has a vast capacity to produce electricity from it. It is estimated to be around 60,000 megawatts. Approximately only 16 percent of this potential is currently being utilized. It is not being utilized to its maximum potential for various factors, including the high costs of installing hydropower plants, constructing transmission infrastructure, and relocating the affected segments of society. It makes around 25% of the entire electricity production in the country.[38]

Pakistan also possesses wind corridors, which have significant potential for the generation of wind-based power. As per some estimation, Pakistan is enriched to create around 50,000 MW of electricity using wind power. It accounts for 4.8% of the overall installed capacity.

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36 *Ibid*., 261.

37 *Ibid*.

38 Dr Ghulam Mohey-Ud-Din, 'Pakistan's Energy Mix and Export Competitiveness', *Business Recoder*, 2023, https://www.brecorder.com/news/40253661.

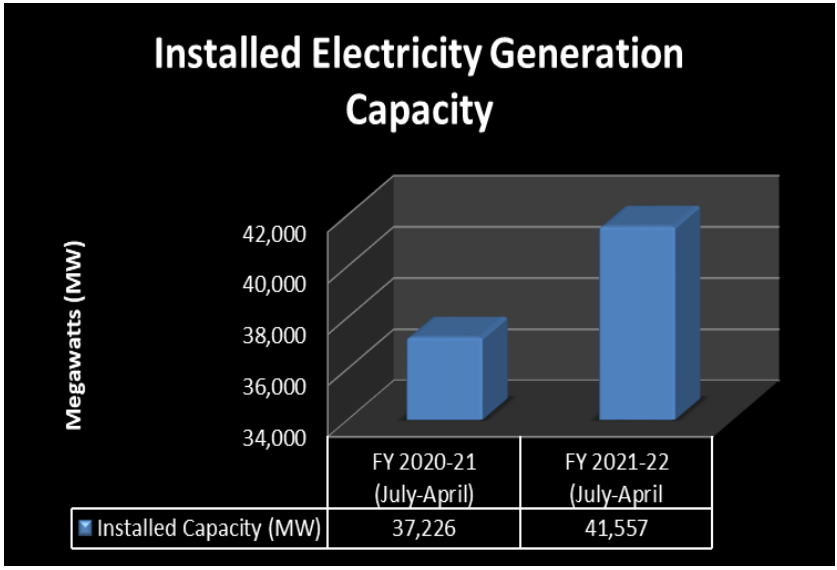
Talking about solar energy, Pakistan has a significant potential for harnessing solar electricity. Sunlight is widely accessible in abundance over the majority of the country. At now, the proportion of renewable resources in the overall energy capacity is very low. However, it is anticipated that this share will see a significant surge in the near future, as indicated by the provisions outlined in the 'Alternative and Renewable Energy Policy of 2019'. Solar installed capacity accounts approximately 1.4 percent of the entire installed capacity.

Pakistan is also engaged in the production of energy through the use of nuclear technology, with its contribution steadily on the rise.

Pakistan's Electricity Generation Capacity

The first four months of fiscal year 2022 saw a positive growth in overall electricity generation capacity, with an increase of 11.5 percent. This resulted in a rise from 37261 MW to 41,557 MW, indicating a promising trend compared to the same time frame in the previous fiscal year as shown in the figure 3:

Figure 3: Installed Electricity Generation Capacity for FY 2021 and 2022[39]

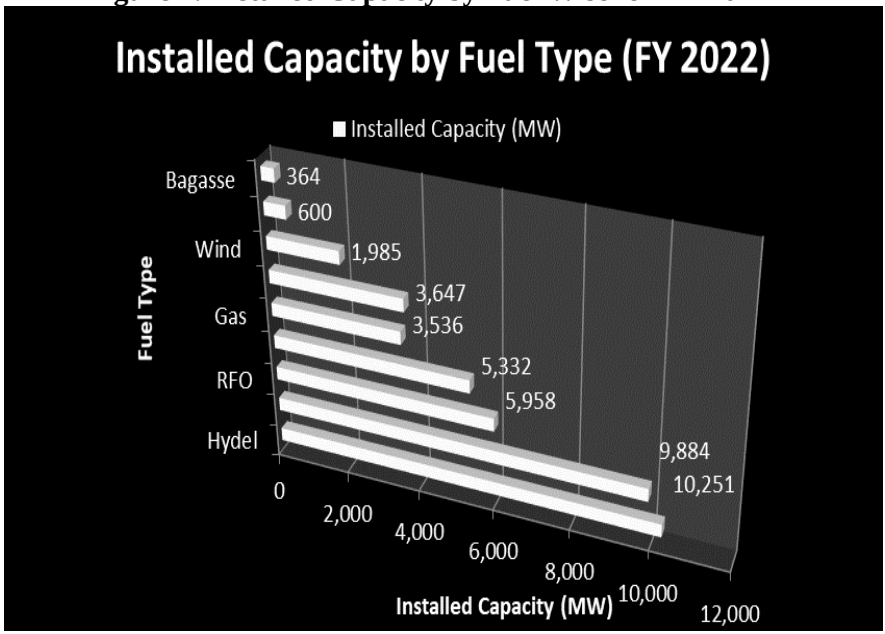


39 Pakistan Economic Survey 2021-22, *op.cit.*, 262.

Fuel Wise Installed Capacity

During the period of July-April FY2022, the percentage share of hydropower in the total installed capacity experienced a slight decrease to 24.7% from its previous year share.[40] Conversely, the proportion of Regasified Liquefied Natural Gas (RLNG) witnessed increase from 19.66% to 23.8% for the same timeframe. An increase was observed in the capacity of coal from 4,770 to 5,332 MW while its percentage share remained unchanged.[41] However, the percentage contribution of gas declined from 12.15% in July-April 2021 to 8.5% in July-April 2022. It is notable that the proportion of renewables got increased slightly, which significantly helps addressing economic and climate challenges of Pakistan. The pictorial display of the fuel wise installed capacity is presented in the figure 4 as follows:

Figure 4: Installed Capacity by Fuel Wise for FY 2022[42]



Share in Electricity Generation

There has been a minuscule reallocation of resources among the various generators of power, expressed as a percentage share. Although there is a

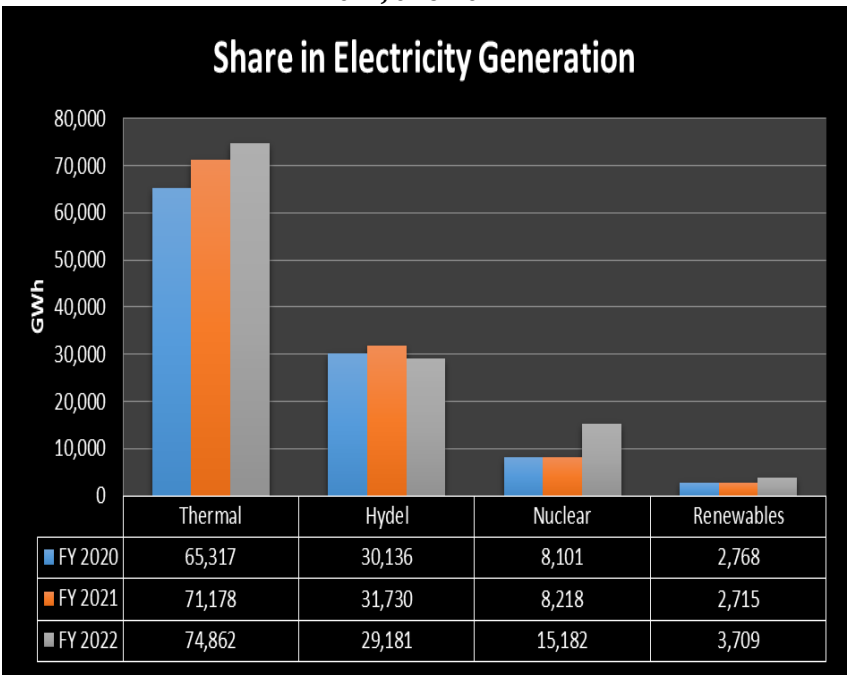
40 M. Jilani, 'Exploring Pakistan's Energy Sector: Sources and Trends', *Current Affairs*, 2023, https://www.paradigmshift.com.pk/pakistan-energy-sector/.

41 Pakistan Economic Survey 2021-22, *op.cit.*, 262.

42 *Ibid*.

slight depreciation from 62.5 percent during the July-April fiscal year 2021 to 60.9 percent during the July-April fiscal year 2022, thermal continues to have the highest part in the country's energy generation. In a manner analogous, the percentage contribution of hydroelectric power to the generation of electricity has decreased from 27.8 to 23.7 percent. The percentage share held by Nuclear rose from 7.2 to 12.35 percent. The percentage of power that is generated by renewable sources has grown from 2.4 to 3.02 percent.[43] The variations in the share of electricity generation by various fuel types for FY 2020, 2021, and 2022 are displayed in the figure 5 below:

Figure 5: Share in Electricity Generation by Fuels for FY 2022, 2021, and 2022[44]



Electricity Consumption

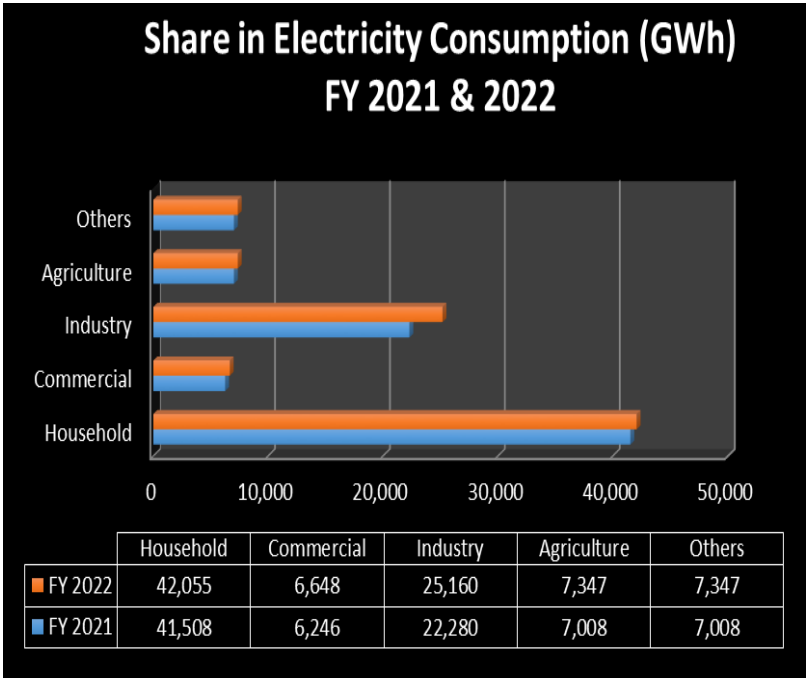
The pattern of power use over the fiscal year 2022 has not been significantly altered in any significant way. The percentage of households who are responsible for the use of electricity has decreased marginally, going from 49.1 to 47.0 percent in FY2022. The consumption in business

43 *Ibid*., 263.

44 *Ibid*.

sector has also witnessed decline, switching from 7.4 to 7 percent.[45] Despite this, Industry's percentage of total power consumption climbed to 28 percent from 26.3 percent during FY2022. The share of energy consumed by the agricultural sector has seen a rise, now accounting for 9% of the total energy consumption, up from the previous 8.9%. In contrast, the percentage of energy consumption by other industries, including public illumination, general services, and various government transportations has decreased from 8.3% to 8%.[46] The share in electricity consumption for FY 2021 and 2022 are represented in the figure 6 below:

Figure 6: Share in Electricity Consumption by Sectors for FY 2021 and 2022[47]



	Household	Commercial	Industry	Agriculture	Others
FY 2022	42,055	6,648	25,160	7,347	7,347
FY 2021	41,508	6,246	22,280	7,008	7,008

45 Muhammad Umer, Saeed. Amber, Khuram Pervez, Rizwan Ahmad, Mina Farmanbar, Muhammad Anser Bashir, Sajid Mehmood and Muhammad Sajid Khan, 'Unlocking Household Electricity Consumption in Pakistan', *Buildings* 11:11 (2021): 566, https://doi.org/10.3390/buildings11110566.

46 Pakistan Economic Survey 2021-22, *op.cit.*, 263.

47 *Ibid*., 264.

Oil Sector

Pakistan's power generation is sourced from a diverse energy mix comprising various fuel types including both fossil and non-fossil fuels. The energy sector exhibits a significant reliance on imported fuel, specifically oil and LNG, due to limited domestic capacity. This dependence on imports is expected to persist in the foreseeable future. The increase in global energy prices and significant devaluation Pakistani currency has resulted in higher costs for oil imports.[48] This has led to interference from outside and an expansion of country's trade deficit. Resultantly, energy import payments have been increased owing to the increase in both value and the quantity demand. The oil import bill experienced a significant increase of 95.9 percent, reaching US$17.03 billion[49] in FY2022. This is in comparison to the amount of US$8.69 billion recorded in FY 2021. Upon further analysis, it was revealed that the import of petroleum products experienced a significant increase in both value and quantity. Specifically, the value of imports rose by 121.15 percent, while the quantity increased by 24.18 percent. The import of petroleum products witnessed a significant increase during the period of July to April in the fiscal year 2022. Specifically, the import value rose from US$3.87 billion in July-April 2021 to US$8.55 billion in the corresponding period of July-April 2022.[50] During the specified time frame, there was a significant increase in the value of crude oil imports, with a rise of 75.1 percent. Additionally, the quantity of crude oil imports experienced a modest increase of 1.4 percent. Between July of FY2022 and April of the following year, the value of petroleum crude oil experienced a remarkable surge, reaching a staggering US$4.22 billion, which represents a significant increase compared to the same period in FY2021, where the value amounted to US$2.41 billion. Throughout this period, the total volume of imported crude oil processed reached one million metric tons, while the volume of locally sourced crude oil processed amounted to an impressive 2.31 million metric tons. Moreover, it's worth mentioning that liquefied natural gas (LNG) imports have witnessed a remarkable 39.86 percent increase during the 2022 fiscal year from July to April. Notably, this increase in LPG is primarily driven by a

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48 S. Mohanty and H. Zamir, 'Pakistan's FY 2022-23 Oil Consumption Declines amid High Prices, Industrial Slowdown', *S&P Global Commodity Insights, 2023*, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/oil/071823-pakistans-fy-2022-23-oil-consumption-declines-amid-high-prices-industrial-slowdown.

49 Pakistan Economic Survey 2021-22, *op.cit.*, 264.

50 *Ibid*., 265.

corresponding 82.90 percent increase in value, indicating a strong demand for this resource.[51]

Gas Sector

While it still accounts for 33.1% of the country's major energy supply, domestic natural gas production has dropped by about 5% in recent years. There are around 13,513 kilometers of transmission gas pipes, 155,679 kilometers of distribution gas pipelines, and 41,231 kilometers of service gas pipelines in Pakistan, according to data for July 2021 through March 2022. There are now more than 10.7 million consumers in the country, up from 10.3 million in 2015. The government's efforts to increase domestic gas output to satisfy rising energy demand were successful.[52] Two Floating Re-gasification Storage Units (FRSU) can convert 1200 MMCFD of RLNG into raw natural gas at this time. To manage the gap of demand and supply in gas, RLNG imports are being made. From July to March of FY2022, the average use of natural gas fell from 3,723 to 3,565 MMCFD.[53] The period of July 2021 to March 2022 is expected to witness the delivery of 863 MMCFD of RLNG. During this time, SNGPL and SSGCL, the two gas utility companies, have taken a giant stride towards expanding the gas network by installing 67 kilometers of gas transmission network, 3,244 kilometers of mains, and 829 kilometers of service lines. This will enable the connection of 108 villages and towns to the gas network, providing access to natural gas to the populace.[54]

Compared to the previous fiscal year, where 304,573 additional gas connections were provided, the period from July to March has seen the supply of 259,212 extra gas connections. This remarkable feat includes 257,644 household connections, 1,473 commercial connections, and 95 industrial connections. The future looks bright, as it is projected that an additional 736,060 customers will gain access to gas in the next fiscal year. The planned investment promises to improve the gas network infrastructure further, ensuring that more people can enjoy the benefits of using natural gas. Figure 7 below reflects on sector wise consumption of natural gas in MMCFD:

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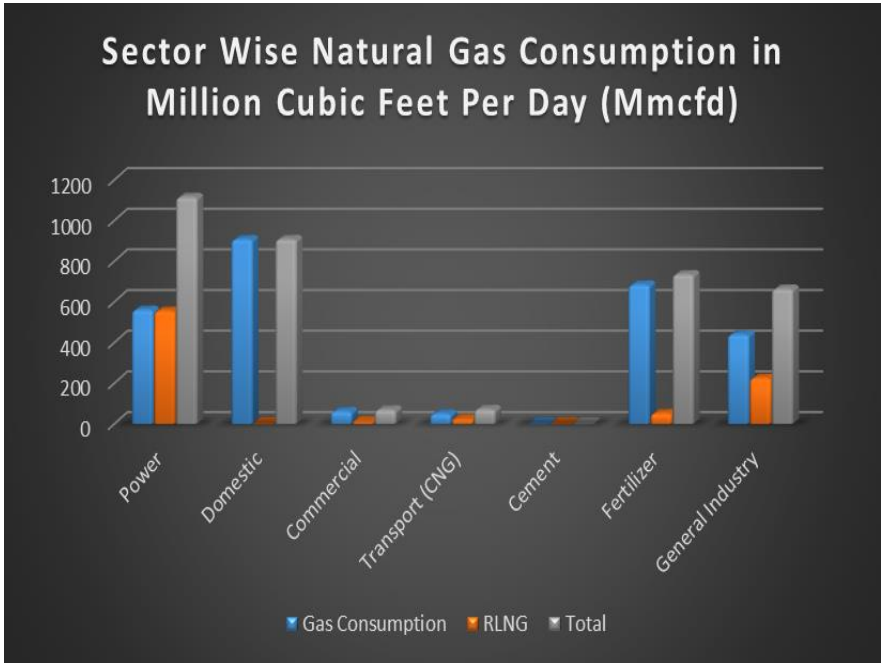
51 S. Mohanty and H. Zamir, 'Pakistan's FY 2022-23 Oil Consumption ….', *op.cit*.

52 Muhammad Yousaf Raza and Boqiang Lin, 'Natural Gas Consumption, Energy Efficiency and Low Carbon Transition in Pakistan', *Energy* 240 (2021), https://www.sciencedirect.com/science/article/abs/pii/S0360544221027468.

53 Pakistan Economic Survey 2021-22, *op.cit.,* 265.

54 *Ibid*., 265.

Figure 7: Share in Gas Consumption by various Sectors for FY 2021 and 2022[55]



Its use in the power industry is now at 560 MMCFD, down from 610 MMCFD previously. Additionally, the consumption of petrol in the home sector went down during the first three months of the fiscal year 2022, going from 915 MMCFD in the same time the previous year to 907 MMCFD. A decrease in the usage of petrol was seen in the commercial sector of Pakistan Economic Survey 2021-22, and the sector's consumption of petrol reached 62 MMCFD from July to March of the fiscal year 2021-22.

Nuclear Energy

The government has previously devised multiple policies aimed at fostering the growth and advancement of Pakistan's power sector. They were aimed at addressing inefficiencies in the current GTD systems of Pakistan's power sector. Additionally, the policies were aimed at diversifying the energy generation mix by maximizing the use of local energy resources. The ultimate goal was to ensure the provision of reliable, affordable, and environmentally friendly electricity.

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55 *Ibid*., 265.

'Pakistan Atomic Energy Commission' (PAEC) is responsible for nuclear power development in the country. Nuclear power has been used by the PAEC to generate electricity within Pakistan for many years. The 'Karachi Nuclear Power Plant' (KANUPP) began operating on August 1, 1971, and completed 50 years of safe operation. The facility has now been permanently shut down for decommissioning. This achievement of providing affordable electricity to the people of Pakistan is a source of national pride.

There are six nuclear power plants (NPPs) that are operational including K-2, K-3, C-1, 2, 3, and C-4.[56] These power plants had a gross capacity of 2530 MW in the previous fiscal year and provided around 7,076 million units of electricity to the national grid from July 2020 to March 2021. In 2022, it rose to 3,530 MW, and they have supplied a total of 12,885 million units of electricity to the national grid between July 2021 and March 2022. This indicates a 39 percent increase in megawatts (MW) and an 82 percent increase in units supplied.[57]

Despite the challenges posed by the COVID-19 pandemic, nuclear power plants (NPPs) have shown remarkable resilience by ensuring the consistent and uninterrupted supply of power at their highest capacity factors. PAEC is currently planning to construct a new plant in the vicinity of Chashma, near Mianwali. This new power plant will further strengthen Pakistan's energy sector by providing more affordable electricity to the general public. With the continuous growth of the country's nuclear power generation capacity, Pakistan is moving towards achieving its goal of becoming a self-sufficient and prosperous nation[58]. The amount of electricity sent to the national grids by various nuclear power plants is shown in the figure 8:

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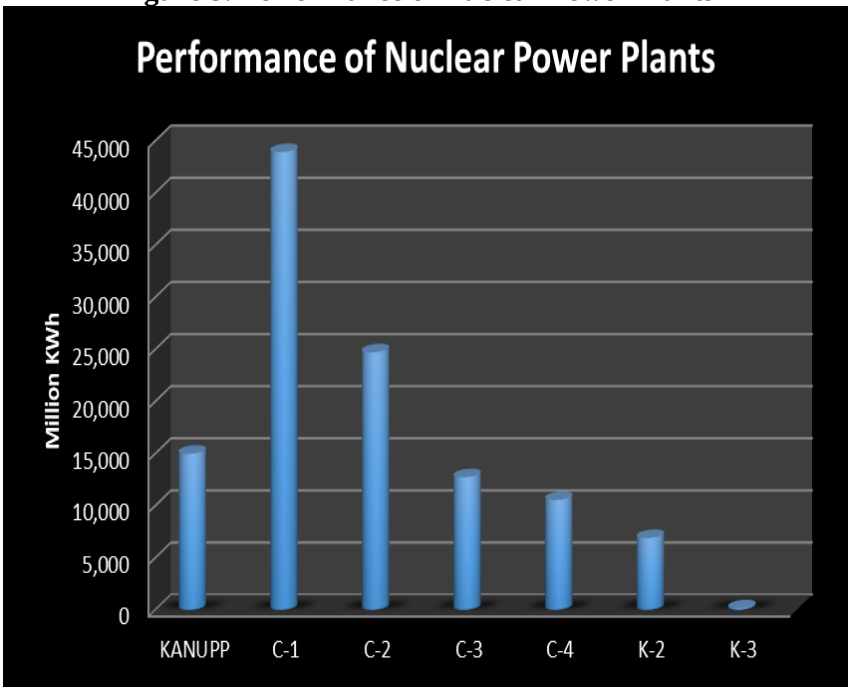
56 'Country Nuclear Power Profile: Pakistan', *International Atomic Energy Agency* (IAEA), 2022, https://cnpp.iaea.org/countryprofiles/Pakistan/Pakistan.htm.

57 Pakistan Economic Survey 2021-22, *op.cit.*

58 'Nuclear Power in Pakistan', *World Nuclear Association*, 2023, https://world-nuclear.org/information-library/country-profiles/countries-o-s/pakistan.aspx.

Figure 8: Performance of Nuclear Power Plants[59]



Mineral Sector

Coal is a crucial energy source, with a substantial portion being utilized by the power sector for electricity generation. Typically, coal from local reservoirs is utilized in various sectors including power, cement, and steel production. In the fiscal year 2021, the country produced approximately 9.3 million tons of coal and imported around 18.9 million tons. Between July and February of fiscal year 2022, the total coal import amounted to 12.21 million metric tons. The coal utilization witnessed a significant decline in cement industry, dropping from 37.6% during the period of July-March FY2021 to 24.1% in the corresponding period of July-March FY2022.[60] Conversely, there was a notable increase in coal consumption, which rose from 19.7% to 31.4% during the FY2022. The power sector is the largest consumer of coal, with its share increasing from 42.7 percent to 44.5 percent during FY2022.[61]

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59 Pakistan Economic Survey 2021-22, *op.cit.*, 266.
60 *Ibid*., 267.
61 *Ibid*.

Pakistan's Renewable Energy Potential

Pakistan's energy future is still very uncertain. Pakistan's energy sector is deemed one of the major hurdles in the smooth economic drive of the country. Though Pakistan has managed to reduce power outage in the country significantly, but overreliance on expensive imported fuels has caused huge circular debt in the energy sector of the country and damaged the environment. As per 2021 report published by NEPRA, only 25 percent of the entire installed capacity comes from hydro and just 5.4 percent comes from the renewables. Majority of the renewable energy comes from wind, solar, and through biomass in Pakistan.[62] RE entails a great future and its significance is reflected in the energy policies adopted by Pakistan. As per 'Renewable Energy Policy 2019', 60 percent of energy is projected to be driven from renewables including hydro till the end of 2030.

Wind Energy: Pakistan is highly enriched with potential in wind energy. This potential is located in the southern regions of Pakistan, particularly in Sindh and Baluchistan. As per the statistics provided by 'Pakistan's Meteorological Department,' Pakistan has the capacity to produce 50,000 MW of electricity by wind turbines. Currently, 26 privately owned wind projects are operating in the country producing around 1335 MW electricity. Another 10 projects capable of producing 510 MW electricity are under construction.[63]

Solar Energy: The sun keeps shining in Pakistan throughout the year for an average nine hours a day. It was incorporated into Pakistan's energy mix back in 2013. There are six solar plants with the capacity of 430 MW are conducting operations and are connected to the national grids in Pakistan.[64] Keeping in view the rate of electricity per unit and challenges on the supply lines, solar energy is the most attractive and viable option, hence a great temptation for industrialists and governments. This sector is projected to attain huge quantities of power generations in the years to come not only in Pakistan but also the world around.

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62 Waqas Ahmad Watto. Xin, Yongrong, Muhammad Khyzer Bin Dost and Hamza Akram, 'Analyzing Pakistan's Renewable Energy Potential: A Review of the Country's Energy Policy, Its Challenges, and Recommendations Sustainability', *Sustainability* 14:23 (2022), https://doi.org/10.3390/su142316123.

63 Pakistan Economic Survey 2021-22, *op.cit.*, 271.

64 *Ibid*.

The national grid in Pakistan is currently supplied with electricity from six solar power projects with a combined capacity of 430 MW. These are primarily found in Baluchistan, Punjab, Sindh, and Kashmir. With one of the largest solar plants in the nation and a capacity of 100 MW peak over a covered area of 500 acres, the Quaid-e-Azam solar park is located in the desert region of Lal Sohanra in Cholistan, Bahawalpur.

To address the country's energy crisis, the current administration has launched a comprehensive National Solar Policy for the provision of affordable, environmentally friendly solar energy. To make the most effective use of solar energy in the nation, all of these initiatives must be pursued with utmost consistency, tenacity, and hard work. To take advantage of the sustainable method of electricity generation, net metering should be widely available to consumers in the nation. This is thought to be crucial for achieving energy independence for the nation in order to reduce problems with power theft, circular debt, and distribution losses.[65]

Hydro Energy: Prior to the advent of wind and solar energy, hydropower was the only renewable energy source available and one of the most sought-after energy sources. Hydropower offers a number of benefits, including the ability to start instantly, the ability to provide black start functions in the event of a grid failure and restart, the ability to store energy through pumped storage, and the ability to provide base load power when it is available. It doesn't need any fuel other than water, which is also a flaw because drought reduces reliability and results in production losses. Droughts that continue and follow one another can be very harmful to the economy and the energy supply.

There is currently 1,360 GW of installed hydropower capacity, or 17% of the world's total capacity, with 391 GW in China, 109.4 GW in Brazil, 82.3 GW in Canada, and 101.9 GW in the United States. Hydropower generates 93.4%, 63.5%, and 58.8% of the electricity in Norway, Brazil, and Canada, respectively. The installed hydropower generation capacity in Pakistan is approximately 10,000 megawatts, or 15% of the 60,000MW total hydro potential. Due to the Himalayas, it has been a highly sought-after source of electricity in our region, including India, Pakistan, and Nepal.

With a revised RE Policy, there are opportunities for the development of small-mini-micro hydro power in addition to large hydro. Small hydropower projects are viewed favorably by the GoP as a cheap

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65 A. Raheem, A. Abbasi and S.A. Memon et.al., 'Renewable Energy Deployment to Combat Energy Crisis in Pakistan', *Energ Sustain Soc* 6:16 (2016), https://doi.org/10.1186/s13705-016-0082-z.

and clean source of energy. The majority of Pakistan's small hydropower projects are found in the country's remote north.[66]

The cheapest source of electricity has proven to be large hydroelectricity. Despite the high availability of hydropower resources, the utilization of this potential source is hampered by low investments in this industry. The micro-hydropower industry has only recently become comparatively well-established. Since the middle of the 1980s, 40,000 rural families have had access to electricity from micro-hydro power plants. The Northern Areas and Chitral are home to the majority of the plants. Another promising option for producing electricity off-grid is small hydropower. The small hydropower sector was primarily managed by provincial governments; in 2014, 128 MW were operational nationwide, 877 MW were being installed, and roughly 1500 MW were still available for development. In Punjab and northern Pakistan, there is an immense potential in small hydro-projects.

Waste to Energy: Pakistan produces about 49.6 million tons of solid waste annually, a rise of more than 2.4 percent.[67] Similar to other developing nations, Pakistan has inadequate waste management infrastructure, which has serious negative effects on the environment.

Waste-to-energy (WTE) offers a technologically advanced method of disposing of waste that lowers greenhouse gas emissions, produces clean energy, and recycles metal. WTE is a well-known technological tool for reducing climate change.

Waste-to-energy facilities generate dependable base load power that can be used to power homes, businesses, and other types of buildings at any time. Pakistan has also taken a number of steps to build waste-to-energy facilities there.

The first WTE plant (Lahore Xingzhong Renewable Energy Company Limited) was built in Lahore and had a 40 MW electricity production capacity while generating 2,000 tons less solid waste. The project has paved the way for additional efforts to address urgent waste disposal issues, leading to cleaner cities and a healthier way of life.

In Karachi, a new waste-to-energy facility has been built. Regarding this, the Sindh government started working on building two

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66 A. Sadiqa, A. Gulagi and D. Bogdanov et al., 'Renewable Energy in Pakistan: Paving the Way towards a Fully Renewables-Based Energy System across the Power, Heat, Transport and Desalination Sectors by 2050', *IET Renewable Power Generation*, 2021, https://doi.org/10.1049/rpg2.12278.

67 Pakistan Economic Survey 2021-22, *op.cit.*, 272.

waste to energy plants estimated cost for the plants is $500 million, the plants will start production till December 2023.

Biomass Energy: Approximately 80% of the cultivated area 21.2 million hectares is irrigated out of a total area of 79.6 million hectares. The world's largest contiguous irrigation system is found in this nation. 4.21 million hectares of Pakistan's total land area are covered by forests, or 5%.[68] It has a substantial potential to lessen to power outage by linking electricity produced by biomass to the national grids. In Pakistan's rural areas, a large number of people rely on forests for their food, fuel, and shelter. To meet their domestic energy needs, many people use the forests in unsustainable ways. Consequently, forest degradation and depletion present a serious problem.

Since biomass gasification and the most recent fermentation technology have not yet been adopted in Pakistan, the majority of the country's biomass power is produced in steam power plants. The highest rate of biomass use is in the sugar industry, where every single sugar mill has a biomass boiler for generating electricity. To boost efficiency, some even use high pressure boilers.

Opportunities and Challenges

The immense potential in renewable energy in Pakistan highlighted in the above section presents both with opportunities and challenges to overcome the acute energy crisis of Pakistan. The following section details about the opportunities and challenges for the wide-scale adoption of renewable energy for sustainable energy and climate security:

Opportunities

The huge potential in renewable energy in Pakistan provides the very basis of opportunities to develop renewable energy sources to address the energy crisis in the country. The following points can be considered as opportunities to incorporate renewable energy into the primary energy mix of the country:

Government Support: Renewable energy development has been emphasized by the policy-makers in Pakistan for the last couple of years as it is reflected through ‘Alternative and Renewable Energy Policy 2019’ to relieve its dependency on overseas energy. Pakistan has been bestowed with huge potential in renewables including solar, wind, and biomass etc.

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68 *Ibid*.

The 2019 energy policy reflects on government's support for renewable energy development.[69]

Growing Solar Market: Regarding solar-energy potential, Pakistan ranks among the top countries of the world. Its long sunny days and weather conditions are good for generating solar energy. Solar power is categorized as one of the finest sources or renewable energy for its immense potential for economic development, clean environment, and social equity. Pakistan's solar energy potential is verified by Ernst & Young (EY), an international consulting firm, through its reports that Pakistan's solar market is one of the world's leading markets with an annual capacity of 275 GW.[70] Keeping the solar energy potential and government support for solar energy development in consideration, solar developers have already started to avail this opportunity.

Technological Advances: The world has witnessed huge technological breakthroughs in renewable energy development. It has made its development and use both efficient and affordable, making it an enticing option to power the globe. Pakistan, a country heavily impacted by climate change, has plenty of RE resources which can be utilized to generate clean energy to minimize the impacts of climate change to ensure climate sustainability. Pakistan's location along with its climate and long sunny days make it highly suitable for installing solar parks. Compared to other RE sources, it is relatively more affordable and provides Pakistan with a tremendous chance to become a major player in producing solar energy.

Pakistan is also highly enriched with wind energy potential. The technological advances in wind technology and Pakistan's collaboration with China under CPEC energy projects provide a great opportunity to harness this immense potential for achieving sustainable energy and climate security of Pakistan.

Challenges

Developing and incorporating RE in the primary energy mix necessitates overcoming certain barriers which are given below:

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69 'Renewable Energy in Pakistan: Opportunities and Challenges', *Max Power: Solar Energy*, accessed 25 December 2023, https://www.maxpower.com.pk/news/renewable-energy-in-pakistan-opportunities-and-challenges/.

70 'Renewable Energy in Pakistan: Opportunities and Challenges'. accessed 25 December 2023, https://www.maxpower.com.pk/news/renewable-energy-in-pakistan-opportunities-and-challenges/.

Policy and Regulatory Framework: One of the major barriers in the development of RE is the absence of a consistent policy to harness this RE potential. It is mandatory for the policy-makers of Pakistan to have clear and consistent policy if they expect to entice investors and developers in this RE industry. The investors and developers are recommended to be provided with incentives to make this sector flourishing and prosperous.

Infrastructure and Transmission Woes: If Pakistan needs to capitalize the immense RE potential, the infrastructure needs to be comprehensively improved. The transmission and distribution networks must be revitalized not only to accommodate the increased flow of energy generated through renewable energy sources but also to link these to the market. Pakistan's government, however, seems bit hesitant to make investment in RE owing to its concerns about grid reliability. So, the grid system must be improved. However, if Pakistan successfully overcomes these barriers, there is no doubt that it would be significant player in the global RE market.[71]

Technical and Operational Barriers: There is a growing trend of adoption of RE worldwide as is reliable, clean, and sustainable source of power generation. However, there are some technical challenges that need to be addressed before its wider adoption in Pakistan. These challenges include erratic power supply, insufficient capacity of grids, long distance and outdated transmission networks, and lacking skilled labor etc. In order to address these challenges on pragmatic grounds, it is imperative to have training programs and technological breakthroughs to properly harness this RE potential.

Political Instability: Political instability is another major hurdle in harnessing the true potential of RE in Pakistan. Northwest of Pakistan which inhibits majority of RE sites and potential is politically instable and has hindered investments. In addition, Pakistan's decision not to ratify Kyoto Protocol and its extensive dependency on overseas oil and gas has placed Pakistan in a very uncomfortable position with global donors.[72] This political instability hampers country's capability to generate revenue

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71 'Potential For Renewable Energy In Pakistan and Challenges', Premier Energy: Illuminating Lives Through Renewable Energy, 2023, https://premierenergy.com.pk/potential-for-renewable-energy-in-pakistan-and-challenges/.

72 'Renewable Energy in Pakistan: Opportunities and Challenges'. accessed 25 December 2023, https://www.maxpower.com.pk/news/renewable-energy-in-pakistan-opportunities-and-challenges/.

from RE industries. RE industry can be very helpful by providing much-needed employment opportunities, reducing the concentration of GHGs in the atmosphere, and relieving dependency on overseas energy supplies etc.

Promising Solutions to Address the Energy Crisis in Pakistan

Current ground realities make it clear that eradicating Pakistan's persistent energy crisis with short-term solutions is extremely difficult. By initiating and carrying out these short-term procedures, the severity of the current condition may, nevertheless, be lessened. To combat the current crises, a two-dimensional implementation strategy is needed.

A. Short-Term Remedial Measures

The following actions are immediately needed to be adopted in the short-term to reduce the severity of current energy calamities:

Wind turbines: Wind turbines are a potential answer for addressing the electricity problem quickly. This is because installing wind turbines is relatively quick compared to building dams and nuclear facilities which take roughly half decade to complete, while finishing thermal power plants take at least two to three years. Wind energy has the potential to be a viable and sustainable replacement and contributes significantly to Pakistan's energy needs. Currently, an extensive research is being conducted in the country which is aimed at exploring all the suitable wind sites for establishing wind farms in the country.

Completion of projects on time: Management authorities are required to make sure that all of the nation's under-construction power plants are completed as per their scheduled time. To ensure high level of power generation and to end the issue of overloading, which is a major cause of power outages, timely completion of the projects is a prerequisite.

Establishment of power plants by private entities: Establishment of new power units by private entities ought to be permitted. In order to reduce the power outage in the country, the private sector must play their part by developing various facilities using their own capital and loans in accordance with their plans and viability.

Fixation of inactive power plants: Some power plants in Pakistan are now inactive because of minor issues that could be easily fixed. These power generating machines can be fixed and upgraded with modern technology by spending little amount of money. The findings of a survey

which was conducted back in 2010 reflect that 17.8 million consumers used 92, 480 GWh of electricity while they were only charged for 73,561 GWh.[73] Additionally, it is urgently required to revive these power generation facilities that can help reducing the gap between demand and supply of energy by maintaining smooth stream of energy.

Efforts from customers: The role of customers in eliminating energy crises is very crucial beside power generation. By opting out this strategy, the commercial sector should firmly mandate that retail malls and markets get closed by maximum 10 p.m. Then, an effective directional resident setup can direct the electricity protected from this source to residences. As a result, domestic customers can benefit from the electricity that is saved across the country.

Controlling the outflow in the power supply: This is another vital step that must be taken to mitigate energy crisis. Power theft has become a major concern for the management authorities in Pakistan right now. The practices of power theft by placing hooks on electric wires and meter tampering are worsening the energy crises in the country. Theft of electricity is estimated to have cost the world around $25 billion. It is the need of the hour to raise awareness among the general population about power theft and treat it like a heinous crime. The administration and the relevant institution should formulate clear policies and severe measures must be taken against those who violate them.

Eradication of irregularities in bills: This is another significant issue which needs to be resolved on urgent basis. Due to ignorance on the part of organization or defective equipment, several businesses fail to measure electricity precisely. Later, billing employees on an estimated lower amount by changing it in the computers creates another issue that needs to be resolved. Similar to the previous example, another anomaly in electricity bills is caused by corruption and bribery. Employees and stakeholders in the industrial and agricultural sectors should be given instructions on implementing new and efficient energy and water usage methods.

B. Mid-Term Remedial Measures

Upgradation of governance system in power sector: The power sector's governance has to be improved. Power generation units must be upgraded

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73 Pakistan Economic Survey 2021-22, *op.cit.*, 272.

regularly with advanced standards because they are operating at comparatively low efficiencies. It will eventually aid in increasing effectiveness and decreasing negative environmental impacts.

Fixing the line losses: About 20% of the losses are attributed not only to grids but also to transmission systems. There is a dire need to reduce by following the global standards aimed at minimizing energy losses.

Adoption of efficient energy strategy: In order to remove poor and ineffective devices from the market square, an energy efficiency mechanism will be developed, and the adoption of production standards for electrical equipment should be ensured.

Allocation of R&D fund: To enable universities and R&D organizations to categorize specific remedies for familiarizing and distributing the employment of renewable energy, a specific R&D fund from the annual budget for RE must be provided.

Long-Term Remedial Measures

Beside short and mid-term remedial measures, the following long-term measures are anticipated by keeping in view the expected increase in the consumption of energy in the days to come:

Use of coal for power production: Pakistan is thought to have the third-largest and of relatively good quality coal deposits in the world. A 33.0 trillion tons coal deposit is being created in Thar, in the country's southeast. Exploiting this resource can help addressing the energy crises in the country if it is to be utilized for power generation. This may provide a safe passage out of this issue. Global surveys and analyses on the comparative cost of power generation through coal and other fossil fuels have revealed that the power production cost from coal is considerably less than that of furnace oil and diesel. Furthermore, results from these surveys reflect that with 2% utilization of coal from Thar deposits around 20,000 MW of electricity can be produced.

Establishment of new nuclear plants and dams: Adding more nuclear power plants and building dams of varying power generation capacity in Pakistan is the key for meeting the increased demand keeping in view the inherent potential of Pakistan in hydropower. The Regime can make use of the technological expertise in the sphere of dam creation of various Chinese and Norwegian firms to fabricate hydroelectricity. Along with

producing electricity, building new water reservoirs and dams is crucial for halting the escalating water shortage issue.

Rehabilitation of obsolete transmission network: This is another promising long-term solution to mitigate energy crisis of Pakistan. Such steps can put an end to the country's ongoing problem with the line losses and holdups by dishonest customers.

Reallocation of gas for power generation: The results from the global surveys and analysis demonstrate that the cost of producing electricity for home use with natural gas is roughly Rs. 6 per kWh, compared to Rs. 14.5 per kWh when using furnace oil. Unfortunately, the natural gas allocation for power production has decreased from 53% over the past five years to 27%. On the other hand, from 17% to 38%, furnace oil is now used more frequently to generate electricity. This approach increased the cost of generation by Rs. 130 billion in 2010, which resulted in mounting circular debt and higher electricity rates. Reallocating gas to power generation, which should take precedence over other sectors, is the answer to a long-term solution for the country's power dilemma. This method can be used to diffuse the situation.

Good relations with energy-rich countries: In terms of long-term predictions and objectives, upholding the national orthodoxy pertaining to its financial and energy needs is crucial. The Pakistani government must strengthen links with present and potential future energy-rich nations. This factor should not be disregarded in order to gain from the economic and systematic aid for the electricity sector.

Adoption of smart grid and meter technology: The implementation of smart meters, the integration of smart grid technologies, and the ability to isolate problematic elements in the event of a serious fault can all contribute to the best possible solution for national electricity savings.

Mixed power generation plants: The mixed electricity generating plants, such as solar/wind, solar/biomass, and wind/hydro, are very important for the production of electricity. To address Pakistan's energy difficulties, such projects should be put in place and the electricity generated by them should be sent to the country's national grid.

Conclusion

This study concludes that the last two decades have witnessed varying levels of power outages in Pakistan that usually last for 10-14 hours in urban areas and 14-20 hours in countryside. It has not only caused severe economic damages but also triggered unrest among masses and political turmoil in the country. Furthermore, Islamabad had adopted various short, mid, and long-term remedial measures and offered incentives to private enterprises in the energy industry at very economical prices. Installations of hydropower projects, a promising long-term remedy for resolving energy crisis, were promised in the past time and again in the shape of Kalabagh Dam but it is very unfortunate that it is not materialized yet. Some small hydropower projects are under construction in the country which is good sign for achieving energy and environmental sustainability. Thermal energy still occupies a maximum proportion of Pakistan's primary energy mix and rapid fluctuations in energy prices in the international market have caused huge economic losses and rising prices of electricity have become a major concern for the citizens. Keeping the magnanimity of the situation in consideration, employment of the immense indigenous potential in renewable energy, particularly in wind and solar, has become the need of the hour. It is also concluded by this study that the two administrative units of Pakistan; Sindh and Baluchistan, provide plenty of suitable sites for wind farms. A good number of wind farms are already being installed in Sindh under the umbrella of CPEC power projects. This study is concluded with the finding that the inherent potential of Pakistan in renewables is immense and its effectiveness to ensure energy and environmental sustainability of Pakistan by its proper exploitation and employment is an undeniable fact. Lastly, this study has recommended pragmatic solutions for their proper utilization to overcome the energy crises of Pakistan and provided new avenues for future research on this topic.

Policy Recommendations

In order to address the energy crisis of Pakistan in the light of above discussion, some policy recommendations are made and if these measures are effectively implemented they can help the governments to have inclusive, effective, and economically viable energy policy.

- A policy of gradual and steady replacement of fossil fuels with renewable energy for power generation should by adopted by the government.
- In order to facilitate sixty million off-grid population of Pakistan, the government should establish Rural Electrification Board (REB) which is meant to provide electricity to the sparsely populated areas with RE.

- Keeping the energy affordability in consideration, an important component of energy security, the government should make an effort to reduce cost of power generation and acceleration of establishment of wholesale power market can be very effective to achieve this objective.
- The government should make it mandatory to utilize a specific portion of the revenue generated by fossil fuel plants to be re-invested in RE plants as a cover for healthcare and environmental damages particularly in the countryside of Pakistan.
- Community schemes by reverse auctions should be facilitated by the government to ensure more rooftop solar projects. Such schemes have produced phenomenal results in London by significantly improving solar uptake and reducing costs around 15-20 percent.
- Private investment may be allowed in the transmission network to avoid extra capacity. NTDC has underperformed to connect every IPP which has caused huge losses.
- Measures aimed at energy efficiency should be emphasized in all the transmission, distribution, and utilization by consumers. Grid digitization and smart metering can be very effective to achieve this end.

Last but not the least measure could be to incentivize consumers to invest in sophisticated energy products by credits. In the transportation sector, induction of hybrids and Electric Vehicles (EV) should be facilitated to increase fuel efficiency.