

**RESEARCH PAPER****Pakistan's Energy Conundrum: Assessing Barriers to Sustainable Energy-Mix on the Road to Net-Zero****¹Muhammad Manzoor Elahi* ²Hafsa Mustafa and ³Dr. Ahmad Raza Khan**

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***Corresponding Author:** mmelahi@gcu.edu.pk**ABSTRACT**

The research delves into energy conundrum of Pakistan and examines the barriers in transition to its sustainable energy mix. Climate change has emerged as one of the biggest warnings to human existence in the 21st century, thereby, the global community urges for an inclusive and equitable approach to energy transition on the road to Net-zero under SDGs like 'Affordable and Clean Energy', and 'Climate Action'. The nexus of energy security and environmental sustainability is a critical debate. The study, therefore, applies qualitative-cum-quantitative mixed method approach to access barriers to generation mix. The study finds and concludes that over-reliance on fossil fuels, lack of political will, fewer incentives for renewable energy, lack of decentralized energy and differentiated systems are the critical barriers on the road to a sustainable energy-mix. It recommends redefining contracts with IPPs, incentivizing solarization and green- metering, supporting micro-grid installation etc., to achieve energy optimization and de-carbonization.

KEYWORDS Climate Change, Decentralized Energy System (DES), Energy-Mix, Fossil-Fuel, Net-Zero, Renewable Energy, Sustainability**Introduction**

Energy is the most important commodity for economies of the modern world. The techniques in the generation, conservation and consumption of energy have seen significant change to ensure an inclusive and equitable society. Under UN Sustainable Development Goals (SDGs) energy security and sustainable economic growth are conditioned with the provision of affordable, reliable and eco-friendly energy sources. This goal can only be achieved with the incorporation of a maximum portion of renewable energy in the total energy mix. Nevertheless, it is rather challenging for many developing countries, such as Pakistan, to meet the global pledges of net zero.

The world witnessed an acceleration in the use of fossil fuels (coal, oil and natural gas) to meet the burgeoning energy demand that further contributed to the emission of Greenhouse Gases (GHGs) in the environment. Alarmingly, the energy demand is increasing exponentially, thereby, ringing the bells of an 'energy emergency' for policy-makers to navigate this challenge. A study mentions that within a period of two decades -1990 to 2019- the worldwide primary energy supply increased by 66%, whereas, energy consumption increased by 130% (Khatri, Mirjat, Harijan, Uqaili, Shah, Kumar 2022).

It is pertinent to note that, to meet the burgeoning energy demand, the post-COVID-19 world has experienced an unbridled use of coal to revisit the industrial growth in the world (IEA 2021). The United Nations (UN) has intimated the wrath of

climate change by pointing out its effects in the form of melting ice, heat waves, non-seasonal rain spells, floods, droughts and abrupt unusual seasonal patterns. It has been mentioned that our planet is quickly approaching the tipping point that could make climate change irrevocable, converting it into 'climate carnage' (Hassan 2022).

Indeed, one cannot deny the fact that the developed world is responsible for largely irreversible climate change whereas, the developing economies of the global south, like Pakistan, are facing more hard effects of it. The Global North has built its empire at the expense of climate challenges to the Global South. They developed their economies by strengthening their energy sector with non-renewable energy. It is reported that around 57% of the energy supply globally depends upon the leading fossil fuels which are oil and coal (Nadeem, et. al., 2023;IEA, 2023).

However, on the road to carbon neutrality over the recent past, the Global North has endeavoured to diversify energy portfolios in a bid to achieve rational percentages of sustainable energy in the global mixture depending upon solar, wind and hydropower. Although Pakistan is endowed with a high capacity of renewable energy resources, their utilization has been somehow limited due to several critical factors i.e., lack of strong political will, irrational policies and bizarre measures, scarce funds, as well as poor physical structures. In other words, there are uncertainties as to how energy security, economic development and low-carbon sustainability interact. Against this backdrop, the drive for such energy transition and economic development in the global south is increasing challenges to the energy mix (Romero-Muñoz et al., 2019).

Additionally, for developing economies, it is more difficult to meet the challenges of energy demand and adopt the non-conventional renewable energy system. Taking the benefit of Pakistan's considerable non-conventional energy sources, policymakers need to devise an unconventional energy plan. The policymakers have many plans in the pipeline but they have not seen the daylight, because governments have failed to put them into action. Pakistan faces a critical juncture in its energy policy. Despite the urgency of climate change and the global commitment to achieving net-zero emissions, the country's energy mix remains heavily reliant on fossil fuels. In 2022, fossil fuels accounted for nearly 66% of Pakistan's total energy consumption, with natural gas constituting the largest share (38%) followed by oil (28%) (World Bank, 2023).

This reliance on fossil fuels results in numerous problems, blocking Pakistan's path to a sustainable and climate-resilient future. Additionally, we are facing an ever more urgent push for a transition to low carbon due to climate change. The Intergovernmental Panel on Climate Change (IPCC) mentioned that if global warming is not stopped at 1.5°C then it will add more vulnerabilities to Pakistan, which is already suffering from climate-induced events such as floods, drought and heatwaves (IPCC 2022).

Pakistan, therefore, is working on the formulation of the updated Nationally Determined Contribution (NDC), which aims to decrease carbon emissions to 15 per cent through the country's resources and 35 per cent with the support of international grants by 2030. To reach this target, Pakistan set the goal to move to 60 per cent renewable resources, 30 per cent electric vehicles and a complete ban on imported coal by 2030 (NDC, GoP 2021).

This research, therefore, delves into the exploration of critical factors that hinder a shift toward a cleaner energy mix in Pakistan. Analysing the stumbling blocks on the

way to net-zero, helps policymakers in Pakistan to neutralize the impact of the transition burden to ensure a stable and sustainable future.

Literature Review

Why Energy Mix?

The energy mix is the combination of renewables and non-renewable energy sources to meet the daily energy demand in line with the global net-zero pledges. The debate on the optimal energy mix is multi-dimensional that not only encompasses economic development and energy security but also discusses environmental sustainability, technological feasibility as well as social acceptance.

The main issue is how nations can balance these factors to have a sustainable and clean energy future? Proponents of energy mix argue that relying too much on a single energy source can lead to economic vulnerabilities. For example, countries that are heavily dependent on oil imports are prone to price volatility and supply disruptions (Cherp & Jewell, 2014). On the other hand, a diversified energy mix can improve energy security and economic resilience. Goldemberg (2000) notes that developing countries often rely on a mix of traditional biomass and coal which are available and affordable but come with big environmental costs. For instance, Pakistan is an epitome of a negative energy-mix as its energy equation is unbalanced and has over-reliance on fossil fuels i.e, furnace oil, coal and Liquefied Natural Gas (LNG) (Ashfaq, T., et. al 2023).

Therefore, critics of fossil-fuel dominated energy mixes emphasize the urgent need to mitigate climate change by reducing carbon emissions. Fossil fuels, particularly coal, are significant sources of greenhouse gases (IPCC, 2021). The transition to renewable energy sources is seen as crucial for environmental sustainability. According to the International Renewable Energy Agency (IRENA, 2020), advancements in renewable energy technologies have made wind and solar power more cost-competitive, providing viable alternatives to fossil fuels. Indeed, the transition is not without challenges, as renewable energy sources require substantial initial investments and infrastructure development (Lund et al., 2015).

The feasibility of integrating renewable energy into the existing energy grid is a topic of debate. The technological advancements have come a long way but energy storage and grid stability is still an issue. Smart grids and advanced energy storage solutions like lithium-ion batteries are needed to manage the intermittency of renewable energy sources (IRENA, 2020). But some argue that fossil fuels are still needed for a stable and reliable energy supply especially in areas with less developed infrastructure (Stevens, 2012).

In pursuit of a smooth energy mix, government policies play a big role in shaping the energy mix. For example, subsidies for fossil fuels can hinder the growth of renewable energy while incentives for renewables can speed up their adoption (Coady et al., 2017). European Union has implemented various directives to increase the share of renewables and has significantly impacted the energy landscape of its member states (European Commission, 2020). The United States on the other hand has had policy inconsistencies partly due to the lobbying power of fossil fuel industries (Mildenberger, 2020). These differences show the need for consistent and sustained policy support for renewables.

Additionally, some other factors like public acceptance and cultural trends also influence the energy mix because the social dimension of the energy mix debate underlines the need for inclusive and participatory decision-making processes. The public opinion on any energy source can shape energy frameworks and investment decisions. (Wüstenhagen et al., 2007). The community acceptance for renewable energy system is significant for the successful implementation of energy-mix strategy (Devine-Wright, 2005).

Likewise, to make energy-mix a success, the energy security is also a part of the energy mix discourse. A diversified energy portfolio reduces dependence on imported fuels and national security (Cherp & Jewell, 2014). For instance, the United States opted the policy of energy self-reliance through the shale gas revolution. Though it secured the energy security, but raised some voices on environmental sustainability (Stevens, 2012).

Moreover, in comparison to the aforementioned studies, Elkhataf et. al., (2023) provide a unique study of “energy trilemma” derived from UK based World Energy Trilemma Index (WETI), which deals with the ranking of different countries based on their performance on three critical dimensions. For instance, energy equity, energy security and environmental sustainability. This study suggests that only sustainable energy-mix solutions can bring positive results concerning environmental protection to prevent global warming and climate carnage.

Methodological Consideration

The research methodology for this paper entails a scientific structure for detailed investigation into the stumbling blocks to energy mix in Pakistan. A mixed methods approach with qualitative and quantitative data sources is applied to guide policymakers to navigate the energy mix challenge on the road to net-zero.

In terms of qualitative approach, the data collection has been done through a systematic review of recorded interviews of various key stakeholders i.e., field experts in energy security and renewable energy solutions in Pakistan, environmental engineers as well as government officials involved in energy policy-making.

Furthermore, these interviews are integrated with the written documents by doing a comprehensive analysis of existing relevant literature. This encompasses research articles specifically focused on Pakistan's energy mix and its transition potential, books that explore energy security challenges, and institutional reports published by the World Bank, the International Energy Agency (IEA), as well as official agencies of Pakistan.

For data analysis, the research applies a six-step technique of thematic analysis by Braun and Clarke (Braun and Clarke 2006). This involves familiarization with all data sources, generating initial codes to capture key concepts, searching for emergent themes, rigorously reviewing themes for coherence and distinctiveness, defining and naming each theme clearly, and finally, writing up the research findings in a well-structured manner. Additionally, statistical data is integrated alongside the interview transcripts, utilizing the same thematic analysis principles.

Additionally, under the quantitative approach, the research applies comparative-descriptive statistics technique to analyse existing data on Pakistan's energy consumption by energy sources, and renewable energy potential. Data sources encompass the Statistical Review of World Energy, World Bank, International Energy

Agency (IEA), Pakistan Bureau of Statistics, and Ministry of Energy reports etc. This uncovers the quantitative spectrum of Pakistan's energy system and potential opportunities for renewable energy integration.

Results and Discussion

This part presents the research findings based on a mixed-method methodology encompassing both qualitative and quantitative data. The first part evaluates Pakistan's pursuit of an energy mix approach amid global climate actions and compares it with the energy diversification policy of India and Bangladesh to get a better understanding of Pakistan's position in the energy mix. The second phase explores stumbling blocks in the energy mix approach of Pakistan through thematic analysis.

Pakistan's Pursuit of Energy Mix

Pakistan's pursuit of energy-mix corresponds with its pledges to global climate frameworks i.e., UN steered Conference of Parties (CoPs). The top priority is to diversify energy resources to achieve sustainable development by optimal utilization of renewable and non-renewable resources. To address this complex issue, the nation is actively pursuing a diverse energy mix, incorporating various energy sources beyond the traditional reliance on fossil fuels (Pakistan Economic Survey, 2022-23). The government of Pakistan chalked out diverse policy frameworks to guarantee a clean and sustainable supply of energy to ensure energy democracy. Such policies include "The National Power Policy 2013", "The Power Generation Policy 2015" and "Alternative and Renewable Energy Policy 2019 (A&REP)".

However, the latter policy was introduced to assist and consolidate renewable resource development in Pakistan. The National Electric Power Regulatory Authority's 2022 yearly report mentions that Pakistan's current energy mix is dominated by fossil fuels, with thermal power plants contributing nearly 60%, hydropower providing approximately 26%, while renewable energy sources like solar, wind, and biomass contribute a combined 7%. Nuclear power makes up the remaining 7% (NEPRA, 2022). In the fiscal year 2024-25, the Government of Pakistan allocated only 1.36 % i.e., Rs. 253 billion, to the energy sector to promote a renewable mix (Ministry of Finance, Federal Budget 2024-25), which was around Rs. 205 billion in the annual budget 2023-24. Therefore, the energy-mix approach in Pakistan encompasses the following policy goals:

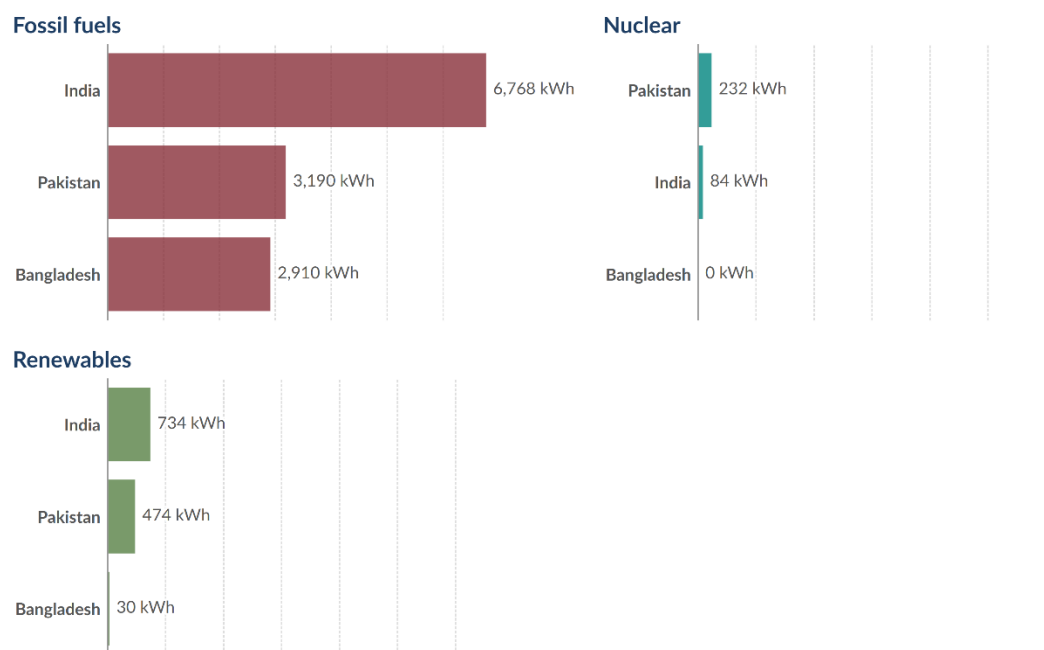
- Firstly, Pakistan's government is pursuing a policy to phase out furnace oil-based power generation in the country.
- Secondly, the government aims to boost the share of renewable energy, particularly via solar, in the energy-mix because of its cost-effective, eco-friendly and easy-to-install nature.
- Thirdly, the government incentivises the production of solar energy by rationalizing the policies like net-metering, green metering etc.
- Lastly, NEPRA aims to upgrade the conventional energy distribution infrastructure to minimize the power transmission losses.

In such cases, resources of renewable energy can play a significant role in filling the gap. In recognizing the limitations of the current mix, the government has ambitious plans to increase the share of renewable energy. The 2030 Alternative and Renewable

Energy Policy aims to achieve a 30% share of renewable energy in the national energy mix by 2030 (Government of Pakistan, 2020). The government is also actively promoting investments in renewable energy projects through supportive policies like feed-in tariffs and streamlined permitting processes.

For this purpose, Pakistan is vigorously striving for the adoption of local, eco-friendly renewable projects as the alternatives of conventional energy resources in its green energy transition. There is a considerable transformation and the involvement of alternate and renewable sources of energy expected in near future.

Figure 01: Per capita Energy from Fossil Fuels, Nuclear and Renewables 2023: A Comparative Study of Energy Mix in India, Pakistan and Bangladesh

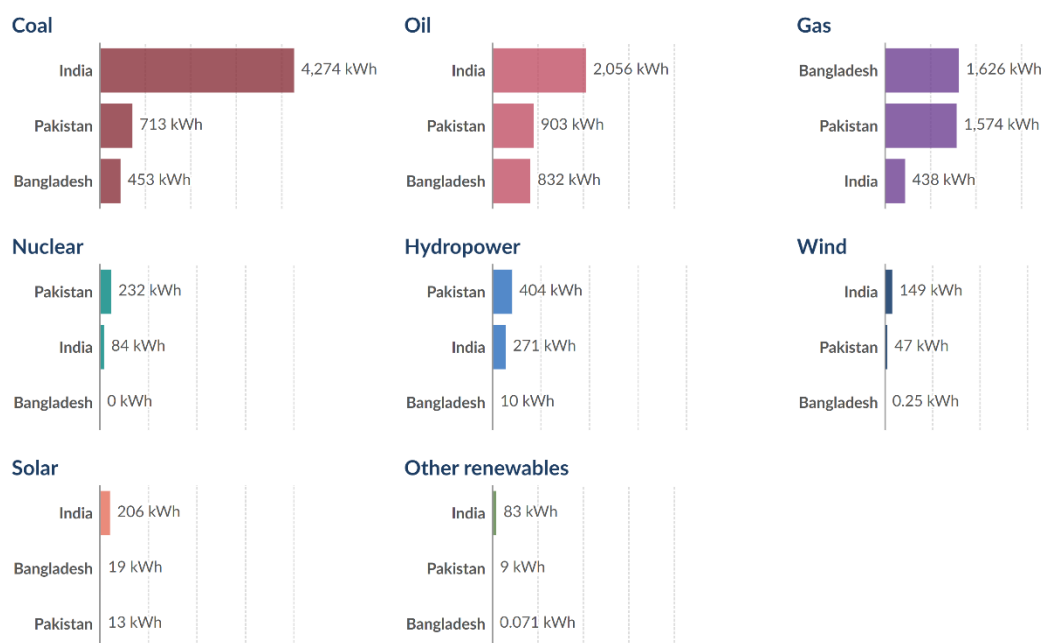


Source: Modified by the authors by editing countries, available at: Ritchie, H., Rosado, P., & Roser, M. (2024). *Energy mix*. Our world in data. Retrieved from: <https://ourworldindata.org/energy-mix>

A comparative study of energy mix approach of India, Pakistan and Bangladesh uncovers that fossil fuels dominate the energy culture in all three South Asian countries. In terms of dependence on fossil fuels, India exhibits the highest dependence (6,768 kWh per capita) compared to Pakistan (3,190 kWh per capita) and Bangladesh (2,910 kWh per capita). This highlights a greater reliance on conventional, but environmentally detrimental, energy sources in India, followed by other two major states of South Asia.

In connection with energy mix approach vis-à-vis nuclear power, Pakistan has a marginally higher nuclear power consumption per capita (232 kWh) compared to India (84 kWh). Bangladesh does not rely on nuclear energy according to the data set. Furthermore, India demonstrates the most developed renewable energy sector, with the highest consumption of renewable energy per capita (734 kWh) followed by Pakistan (474 kWh) and Bangladesh (30 kWh).

Figure 02: Per capita Primary Energy Consumption by Source, 2023: A Comparative Study of Energy Mix in India, Pakistan and Bangladesh



Source: Modified by the authors by editing countries, available at: Ritchie, H., Rosado, P., & Roser, M. (2024). *Energy mix*. Our world in data. Retrieved from: <https://ourworldindata.org/energy-mix>

Furthermore, a comparative study of per capita primary energy consumption by source in Table 02 gives a clearer picture of energy mix approach of Pakistan in compare to India and Bangladesh. The dataset reveals significant variations across India, Pakistan, and Bangladesh. For instance, India leads in coal consumption with 4,274 kWh per person, while Pakistan and Bangladesh consume 713 kWh and 453 kWh respectively. In terms of oil usage, India again tops the list at 2,056 kWh per person, followed by Pakistan at 903 kWh and Bangladesh at 832 kWh. The low-carbon energy i.e., Gas consumption is highest in Bangladesh at 1,626 kWh per person, closely followed by Pakistan at 1,574 kWh, and considerably lower in India at 438 kWh.

For nuclear energy, Pakistan utilizes 232 kWh per person, India 84 kWh, and Bangladesh has no nuclear consumption. Hydropower consumption is significant in Pakistan (404 kWh per person) and India (271 kWh per person), but minimal in Bangladesh (10 kWh per person). Wind energy usage is primarily seen in India (149 kWh per person), with lower consumption in Pakistan (47 kWh) and Bangladesh (0.25 kWh). Solar energy is more prevalent in India at 206 kWh per person, with Bangladesh and Pakistan using 19 kWh and 13 kWh respectively. Other renewable energy sources contribute 83 kWh per person in India, 9 kWh in Pakistan, and a negligible 0.071 kWh in Bangladesh.

Barriers to Pakistan's Energy Mix Policy

Pakistan's energy sector is marked with plethora of issues in its pursuit of energy-mix scheme. Though Pakistan has significant potential for wind, solar and biogas, contrarily, only miniscule of renewable power is the part of overall energy production.

Following are the derived themes that explain the prevailing stumbling blocks on the road to energy mix amid carbon neutrality.

Table 1
Thematic Analysis: Challenges to Energy Mix Policy in Pakistan

Main Themes	Sub-themes
Over-reliance on Imported Fossil Fuels	<ul style="list-style-type: none"> • Over-import of oil/coal instead of renewable • Over-utilization of fossil fuels • Irrational contracts with IPPs • Circular Debt
Financial and Technical Constraints	<ul style="list-style-type: none"> • Insufficient financial assistance for renewable energy projects • Lack of financial and infrastructural support to explore local energy resources • Lack of convenience and expertise in the coal conversion technologies • Incapacity of transmission lines to utilize renewable resources
Disinclination towards differentiated use of Energy Resources	<ul style="list-style-type: none"> • Lack of policy implementation to achieve energy-mix • Less exploration of renewable energy resources • Imbalance between energy security and environmental sustainability • Domino effect of energy related issues towards negative growth
Badly Governed Energy Sector & Policy Imperatives	<ul style="list-style-type: none"> • Dilemma of capacity payments • Mismanaged energy sector intertwined with badly governed climate policies • Inconsistent government policies • Irregular and uneven distribution of energy • Less support and incentives for renewable resources • Shortage of Research & Development (R&D) budget in energy sector
Lack of Decentralized Energy System	<ul style="list-style-type: none"> • Over dominant centralized energy system • Less reliance on indigenous resources • Restricted utilization of small-scale energy generation projects • Ruling out of small entrepreneurs which can otherwise provide alternatives to national grid.

Over-reliance on Imported Fossil Fuel

Pakistan's energy system heavily relies on fossil fuel, around 40 % of its supply is imported. This is one of the biggest challenges to the energy-mix of Pakistan. Natural gas makes up a dominant 42% of the country's energy mix, followed by oil at 26% and coal at 17% (Pakistan Economic Survey, 2023). Due to dominant dependence on natural gas, Pakistan's indigenous gas reserves are dwindling, forcing expensive Liquefied Natural Gas (LNG) imports, straining foreign exchange reserves (Boell Stiftung, 2022).

Such reliance has dual drawbacks, at first, it is carbon-centric and, secondly, the fossil-fuels are not indigenous rather imported energy is making it more costly. Additionally, this is coupled with the monopoly of Independent Power Producers (IPPs) that are highly dependent upon imported fuel like LNG. The Government contracts with IPPs often guarantee high payments regardless of electricity generation, straining national finances, especially during low demand periods (Pakistan Economic Survey, 2023). Furthermore, these contracts are frequently denominated in foreign currencies,

making them vulnerable to currency fluctuations and increasing costs when the Pakistani Rupee weakens (Macro Pakistani, 2023).

Consequently, this contributes to the vicious cycle of circular debt, where the government owes money to IPPs, who in turn owe money to fuel suppliers (The Diplomat, 2019). Table 2 explains the draconian control of IPPs and mentions that the government of Pakistan has faced a gigantic increase of 261 % in circular debt from Rs. 0.729 trillion in 2017 to 2.436 trillion in 2024.

Table 2
Energy Sector's Circular Debt of Pakistan

Fiscal Year (FY)	Circular Debt in PKR Trillion	Increase in %*
2024	2.636	3.33
2023	2.551	2.55
2022	2.626	12.84
2021	2.327	8.21
2020	2.150	33.38
2019	1.612	40.34
2018	1.148	57.47
2017	0.729	--

Source: Ministry of Energy, Power Division of Pakistan. *Increase assessment is based upon percentage calculation made by the authors.

IPPs offer a fast solution, their focus on short-term fixes overshadows investments in long-term sustainable solutions like renewable energy (Khatri et al., 2022). According to an estimate, about eighty five percent of Pakistan's oil demand is fulfilled by imports with billions of dollars of expenditure annually. The import of fossil fuels is a real burden on country's economy. In primary commercial energy supply, from 2013 to 2019, the share of renewable and non-renewable resources has significantly varied. In the period 2013–2014, the proportion of oil in total energy mix was 34.4%, which was reduced to 25.7% till 2019. It is significant to note that the proportion of gas was also reduced from 46.3% in 2013 to 35% in 2019. On the other hand, the proportion of coal consumption witnessed increasing trend and jumped from 5.4% in 2013 to 15.4% in 2019. Other than this, the drop in the total share of the energy mix is in the utilization of nuclear and hydro resources, the proportion of which was decreased from 13.3% in 2013 to 10.7% in 2019. (Ahmad & Derrible 2018).

Financial and Technical Constraints

The establishment of an economically sound energy sector in low-income developing countries is a major problem. The utilisation of renewable energy also demands advanced technology and sufficient measures to achieve the targeted outputs. Pakistan's frail economy sets its energy policies in line with its available domestic resources and the imported fossil fuels. Therefore, the green energy remains far behind while devising the national energy policy. At the root of the challenges are both the commercial and technical losses. Power generation from a number of renewable energy resources has been started in number of areas but they are still at a very small scale due to insufficient financial assistance.

In the race of green energy advancement, one of the major financial and technical constraints is lack of convenience and economic hindrance in coal conversion technologies. A transition towards gasification and liquefaction of coal presents major

financial burden on Pakistan's economy (NEPRA). Even numerous global examples of Coal to gas (CTG) and Coal to Liquid (CTL) techniques present a bleak picture for such projects to be established in Pakistan who is already facing economic instability.

Taking example of Kemper coal-to-gas project of the USA, which attempted the gasification of lignite coal (similar chemical combination that found in Thar, Pakistan), to achieve low carbon coal technology, resulted into failed strategy due to extremely expensive infrastructural and technological setup. Beside this, much higher than expected cost of water utilization during gasification process became a major cause of debacle of this project. Such example manifests the unviability of this technology in Thar which is already a water-stressed region.

Another case is Indonesia, where according to report of Institute for Energy Economics and Financial Analysis (IEEFA), a proposed model of coal conversion into dimethyl ether (DME) will cost hundreds of millions of dollars annually, despite having much lower coal production cost than that of Pakistan. This model is still declared unviable for the country's economy (Nicholas 2021). On the other hand, in case of India, in June 2024, the country has established its first-ever coal gasification project in Jharkhand. It is based upon underground in-situ coal gasification and its conversion into many important gases like methane, carbon monoxide, hydrogen and carbon dioxide, which are anticipated to be used for multiple purposes. Ministry of Coal of India got separate allocation of similar three more projects in the annual budget of 2022-23 (PIB India). Whereas taking account of the financial instability and the fossil fuel subsidies in Pakistan, such projects are still distant dreams. Although, CTL and CTG processes are already present in energy production proposals in Pakistan with the proposed assistance from China in terms of finance and technology, but such projects do not see the daylight due to costs inconvenience and yet-more debt dependency on China. In this way, efforts for environmental sustainability are marred by financial unsustainability, leading to stagnation of coal conversion projects.

The incapacity of infrastructure and loss of transmission lines to absorb maximum quantity of power from green energy sources is a critical barrier in mix-generation. Despite the inclusion of diverse new power plants, the pace of transmission and distribution sector could not go parallel. Consequently, this results into grid failures and technical faults due to overloaded transformers and transmission lines. NEPRA reports 27 % of Transmission and Distribution (T&D) losses for the fiscal year 2022-2023; while 26.5 % for the fiscal year 2023- 2024 and they comprise of both the power theft and technical losses.

Disinclination towards differentiated use of Energy Sources

The dream of energy mix can be realised by differentiated use of energy in different departments. Unfortunately, in Pakistan over-reliance of energy sector is on oil and coal, while differentiated use of energy is not implemented practically. For example in China, the agricultural sector runs only on energy received from biogas while their industrial sector depends upon oil and coal. In this way, China has achieved its energy mix. In the same Chinese pattern, Pakistan can analyse its energy resources in differentiated sectors and use them according to the classification, to achieve its energy mix (Najam 2022).

Energy cost will also be reduced achieving the energy mix. Bangladesh, like China, is also working on policies related to differentiated use of energy. In Bangladesh, the major population has reliance on biomass for heating and cooking purposes.

According to United Nations (UN) report 2022, in Bangladesh, maximum energy required to meet demand for household cooking is compensated through biomass resources (UNSD 2022). According to an estimate, there are 30 million households in Bangladesh, most of which are rural, which are taking advantage of this facility. Remarkable advancement has been done in the sector of renewable energy in the last few years.

On the same pattern, Pakistan can work on differentiated use of energy, aiming at energy-mix. Efforts have been done in this regard i.e. different activities under the initiatives like net-metering, lighting projects in the remote villages were carried out during the fiscal year 2020. For the purpose of maximum utilization of renewable energy technologies, National Electric Power Regulatory Authority (NEPRA) had put forward NEPRA (Alternative & Renewable Energy) Distributed Generation and Net Metering Regulations on September 1, 2015. Those regulations facilitate the implementation of net-metering installations by the usage of solar and wind energy production up to the capacity of 1 MW. For practical usage, the very first such project was installed at the Parliament House, Islamabad which has opened the corridors for net-metering based systems all over the country (GoP, Finance Report 2020). Following the pattern for differentiated use of energy in multiple sectors, analysis can be done to overcome the crisis in Pakistan. Still a lot of work is required to achieve the target of energy securitization of net-zero by utilizing differentiated energy model. In Pakistan, less exploration of renewable energy resources leads to imbalance between energy security and environmental sustainability.

Badly Governed Energy Sector & Policy Imperatives

Pakistan's energy sector suffers from mismanagement, inconsistent policies, and a lack of support for renewable energy resources. These difficulties, coupled with poorly implemented climate regulations, have posed considerable hurdles to the country's long-term development and economic stability.

The dilemma of capacity payment agreements to power plants in energy sector is exacerbating the financial challenges to in handling the green energy transition. These agreements are based upon installed capacity rather than actual power generation. Power Division estimates that capacity payments to IPPs for the fiscal year 2024-25 reached up to Rs.2.1 trillion. This problem of overcapacity is further worsening the circular debt within the power system of Pakistan.

Mismanagement in the energy sector is linked to poor climate measures. Pakistan's energy policies continue to promote fossil fuels, despite the growing effects of climate change. Such disproportion does not only deteriorate environmental conditions but also create insecurities in the energy culture (Najam, 2022). For instance, frequent change in climate regulations and absence of long-term planning are refraining public-private partnership. Such unpredictability discourages investment of private sector in the establishment of sustainable energy infrastructure (Waheed, Fischer, and Khan, 2021).

Irregular and imbalanced distribution of energy between Urban-Rural sectors is another important issue. In Pakistan, metropolitan areas receive a disproportionate amount of energy, whereas rural areas face severe shortages (Khatri et al., 2022). This disparity reduces economic prospects in the marginalized areas, further exacerbating the social exclusion. For instance, the rural community frequently faces power outages that

significantly put negative effects on their agricultural productivity as well as overall quality of life.

Furthermore, diminutive support and incentives to renewable energy hinders the integration of green energy with the central grid. Though, the world is pushing for green energy, Pakistan, unfortunately, stays with the conventional energy sources because of long-standing individual interests, IPPs are the epitome of this. (Asghar et al., 2022). Despite the country's tremendous potential in solar and wind energy, the government officials are still not investing on it for optimal energy use.

Moreover, absence of R&D investment in the energy sector is another impeding factor on the road to energy-mix. Unfortunately, in Pakistan, the energy sector's R&D budget is limited, resulting in reliance on out-of-date technology and practices (Ahmad & Derrible, 2018). Such under-investment slows progress and keeps the economy reliant on inefficient and polluting energy sources. With the high investment in R&D vis-à-vis energy, Pakistan's solar energy take-off can surpass the Germany's solar energy production, which is regarded as the best solar generation plants in the world (Suri et., al 2020; Adil 2021). But the fact is that, the solar energy generation for both the domestic and commercial sectors remain at minimal levels. The incentives and support for consumption of coal-based energy is rather greater than the incentives being provided for solar power.

Pakistan announced a national energy plan in the year 2010; however, it faced much criticism. It ignored the indigenous requirements and imposed bizarre conservation measures i.e., ban on neon billboards, end of night wedding ceremonies and street markets by 10:00 pm. Such irrational measures could not produce desired results. In addition, Pakistan has established the National Electric Power Regulatory Authority (NEPRA), charged with ensuring fair energy competition and consumer protection, but political meddling sabotages its autonomy and efficiency. Shortage of Research & Development (R&D) budget in energy sector has further exacerbated the issue.

Lack of Decentralized Energy System

The decentralized energy system can be defined as the system where the source is located closer to the demand centre. Distributed energy system provides a number of advantages over mega energy projects including lower costs, environmental friendliness, affordability, lower risks, reliability and the capability to cope with the system failures ensuring community empowerment. On the other hand, the centralised energy system is attributed with inequalities and it also exacerbates the 'core-periphery' culture leading to marginalisation of local community. Small scale power generating projects can help to utilise ample renewable resources of energy achieving the energy mix. Pakistan is gradually picking up pace in certain areas to adopt decentralized energy policy. Under the Pakhtunkhwa Energy Development Board (PEDO), for the advancement in hydropower capacity of the province of Khyber Pakhtunkhwa, 56 micro hydro power projects in Chitral's far-flung areas are established. They have the combined capacity of 11 MW within the estimated cost of 5 billion rupees. There is scattered population in Chitral region, thus such small hydropower projects are the most beneficial solution to meet the requirements of energy (Dawar 2023).

According to the report published by Pakistan Business Council (PCB) in 2018, the centralized energy system of Pakistan has resulted into 89% loss of primary energy. If Pakistan adopts the decentralized energy policy then the overall distribution and

transmission loss can be reduced greatly. Moreover, decentralized energy system provides technological agility and efficient results can be achieved by using technological inputs. Using better technology, the cheaper and cleaner resources of energy like those of solar and biogas can provide ample energy resources minimising the carbon emissions.

Decentralized energy system provides the distributed form of energy which can further provide societal benefits in the form of local employment, financial assistance and skill development opportunities. The policy making in energy sector of Pakistan primarily focuses on the centralized energy system rather than decentralized energy infrastructure. Building huge dams require large infrastructures and financial support. Meanwhile, the economy of Pakistan is in struggling phase and such huge projects require large investments. Due to financial constraints these projects take a lot of time to be completed. Currently, rigid regulations in energy sector of Pakistan do not incentivise the small entrepreneur to enable them for the provision of alternatives to national grid. Thus, law needs modification and amendments to ensure inclusion of private parties for the generation and distribution of electricity in bad-grid and off-grid areas (Shah, Rasheed, Ali 2022).

Conclusion and Policy Recommendations

Today, living in 21st century, climate change demands a transition from conventional energy to renewable energy to minimize its unintended effects. Such transition on the road to net-zero heavily depends upon energy-mix strategy because phasing out fossil-fuels at once is catastrophic for current economic cycle in Pakistan. The policy of energy diversification is the optimal solution to this conundrum.

The assessment of renewable resources in Pakistan reveals that they have the capacity to meet the energy-mix demand for a sustainable and clean energy supply. The study mentions that unlike many developed countries (for instance Germany) Pakistan has more photovoltaic power potential but the former is producing more solar energy and known as one of the fastest solar energy beneficiary. Pakistan, despite having favourable geographic condition for hydel, solar and wind power generation is not maximizing its energy security.

The study derives multiple barriers on the road to energy-mix including over-reliance on imported fossil fuels, financial constraints, infrastructural and technical incapacity, disinclination towards differentiated use of energy resources, badly governed energy sector and lack of Decentralized Energy System (DES). These could only be overcome through a robust and effective policy making process in line with local needs.

Furthermore, the study suggests the following policy measures to be taken for a sustainable energy-mix to ensure inclusive and equitable development.

- Revisit the draconian and irrational agreements with IPPs to halt the supremacy of fossil fuels.
- Prioritize the energy diversification approach in the national energy security policy of Pakistan with enhanced focus on hydel and solar energy generation.
- Incentivization for general masses on the usage of solar energy including relaxations on net-metering installation and adjusting green units.

- Strengthen public-private partnership to overcome the financial constraints and technical incapacities to upgrade the power supply infrastructure.
- Seek international support to head towards green energy projects and enhance focus on R&D in energy sector.
- Last but not least, sponsoring micro-grid power stations including solar, hydel and wind to not only streamline a sustainable energy-mix but also to increase energy accessibility for energy poor areas.

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