Engineering a Sustainable Future: SWOT Analysis of Pakistan's 2019 Renewable Energy Policy Design

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Pakistan, as a developing and densely populated country, faces persistent challenges of electricity shortages, heavy reliance on imported fossil fuels, and rising environmental and economic pressures. Despite possessing substantial renewable energy potential, the share of renewable sources in the national energy mix has remained limited, largely due to weak policy implementation. This study systematically examines Pakistan's Alternative and Renewable Energy Policy (AREP) 2019 using a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analytical framework. The identification of SWOT factors is based on qualitative analysis of national policy documents, official energy-sector reports, and peer-reviewed literature, supplemented by expert insights from stakeholders within the energy domain to enhance analytical robustness. The results reveal that AREP 2019 demonstrates strong potential through abundant indigenous renewable resources, investor-friendly provisions, and an improved regulatory framework; however, weaknesses persist in delayed project implementation, grid constraints, and procedural complexities. Opportunities lie in hybrid energy systems, private-sector participation, and carbon-credit mechanisms, while threats include political instability, grid unreliability, energy theft, and regulatory uncertainty. By translating SWOT outcomes into actionable policy insights, this study highlights critical implementation gaps and proposes strategic directions for improving energy security, sustainability, and long-term policy effectiveness. The findings offer practical guidance for policymakers, regulators, and investors seeking to strengthen Pakistan's transition toward a resilient and sustainable energy future.

Keywords: Electricity, Fossil Fuels, Energy Sustainability, Renewable Energy Sources, SWOT Analysis

Introduction:

The swift growth of the energy sector, marked by increased fuel consumption, is causing a significant increase in greenhouse gas (GHG) emissions [1]. Energy is essential for improving living standards, boosting the economy, and driving industrial growth in a country. It forms the foundation for sustainable urbanization and industrialization. Balancing energy use, managing energy sources, and utilizing renewable energy sources (RESs) are essential [2], [3]. During energy generation and consumption, GHGs are emitted, with 41.7% of global GHG emissions attributed to heat and electricity generation. Shifting electricity generation from conventional fuels to RESs can decrease GHG emissions and increase efficiency in electricity generation, according to think tanks [4], [5]. RESs' electricity generation produces nearly zero carbon emissions, contributing to global climate change mitigation. Economically, increasing dependence on RESs for energy generation is expected to reduce electricity costs in the short run [6][7][8].

Pakistan is facing serious electricity shortfalls, about 3-4 h daily. The peak demand was 25000 MW, while electricity generated from all sources was 22000 MW by 2020 [9]. The multiple factors are involve to short the electricity, including heavy T&D losses, continuous use of imported fossil fuel, mismanagement in source use, and improper implementation of power policies [10]. Pakistan is still generating electricity through fossil fuels, which hurts the environment [11]. Recent research indicates that Pakistan possesses significant RES potential, presenting an opportunity to generate electricity and meet energy demands using these sources rather than relying solely on thermal energy [12][13]. Positioned between the latitudes 24° and 37° north and longitudes 62° and 75° east, Pakistan stands in a favorable geographical location for harnessing renewable energy resources [14]. With an annual growth rate of 2%, Pakistan sustains a population of 213 million, securing the 6th position globally. The population distribution reveals that 63% resides in rural areas, while 37% inhabits urban regions. The surge in both population and economic development significantly escalates the energy demand. Presently, the country heavily relies on thermal energy for electricity generation, a choice that poses environmental challenges. To address these issues, the GoP strategically intends to utilize green, cost-efficient, alternative, and renewable energies for electricity generation. Despite the mere 1.1% contribution of RESs to the energy-mix until 2018, the government aims to boost their share to 5% by 2030 [15]. The location of country is ideal for receiving solar radiations, ranging between 4.45 and 5.83 kWh/m^2/day [16] having a potential 149 GW of solar energy [17], power potential installable capacity of wind energy is 346000 MW [18], the hydropower potential exceeds 100,000 MW, with identified sites totaling 55,000 MW [19] and 20,709 MW potential of bio-gas to generate 20,709 MW of electricity [20]. Pakistan can produce 59,536 GWh/ 49.4% y−1/ 226.8 million m3 d−1 electricity from biogas [21]. Despite having a huge potential for solar, wind, hydel, and bio-gas energy, Pakistan is still generating almost 60.9% of energy from thermal power plants, 23.7% from hydro power, 12.35% from nuclear power, and only 3.02% from RESs in the energy mix 2022, as illustrated in Figure 1. Pakistan generates just 3% of energy from RESs despite the government's commitment to use them for electricity generation. Source-wise generation capacity for the last five fiscal years is tabulated in Table 1[22].

Table of Nomenclature

Nomenclature			
AEDB	Alternate Energy Development Board	MW	Megawatts
AHP	Analytic Hierarchy Process	NTDC	National Transmission and Dispatch Company
ARE	Alternative Renewable Energy	NEPRA	National Electric Power Regulatory Authority

DISCOs	Distribution Companies	PV	Photovoltaic
GHG	Greenhouse Gas	RESs	Renewable Energy Sources
GoP	Government of Pakistan	SWOT	Strengths, Weaknesses, Opportunities, and Threats
GW	Gegawatts	TWh	Terawatt Hour
GW/h	Gegawatt Per Hour	WAPDA	Water and Power Development Authority

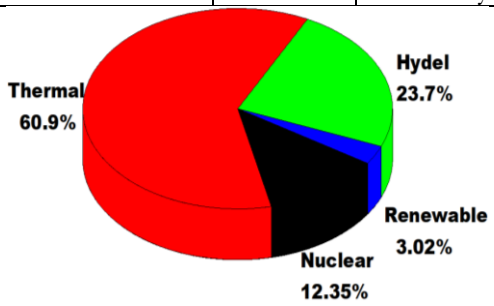

Figure 1. Energy-mix 2022 of Pakistan [22]

Several power policies have been established in order to tackle the electricity shortage in Pakistan. However, the government has not effectively implemented these policies, leading to continued reliance on fossil fuel imports [23][24][25]. The government needs to ensure policy adherence or attract private investors to support these initiatives. Furthermore, individuals in the country can contribute by adopting new technologies, such as rooftop Photovoltaic (PV) solar, which is a reliable, sustainable, and cost-effective solution. In this context, the Alternative and Renewable Energy Policy (AREP) 2019 is subjected to a comprehensive SWOT analysis. The findings of this study serve as a valuable resource for researchers, engineers, and intellectuals within the country, aiding in the understanding of policy shortcomings. Moreover, this research will provide future governments with insights to effectively address these issues.

This study aims to critically evaluate Pakistan's Alternative and Renewable Energy Policy (AREP) 2019 using a SWOT framework. It seeks to identify key strengths, weaknesses, opportunities, and threats of the policy and to derive actionable insights for improving renewable energy implementation and energy sustainability in Pakistan. This study extensively examines the policy through a meticulous assessment of its SWOT. The remainder of the paper consists of five sections. Section 2 provides the literature review, offering a thorough examination of relevant studies. Section 3 outlines the methodology employed to comprehend the policy, while Section 4 provides a detailed analysis of the policy's strengths, weaknesses, opportunities, and threats. Section 5 presents suggestions and a roadmap for the future, and finally, Section 6 concludes the study. Unlike previous SWOT-based assessments of Pakistan's energy sector, this study provides an implementation-focused evaluation of the Alternative and Renewable Energy Policy (AREP) 2019 by integrating updated post-policy evidence, expert-informed validation of SWOT factors, and policy-oriented analysis. The research advances existing knowledge by translating SWOT outcomes into actionable insights that address contemporary institutional, regulatory, and grid-level challenges hindering renewable energy deployment in Pakistan.

Table 1. Source-wise electricity generation capacity in Pakistan [22]

Fiscal Year	Hydroelectric (GW/h)	Thermal (GW/h)	Nuclear (GW/h)	Renewable (GW/h)	Imported (GW/h)
2017–18	27,925	89,614	9,880	3,857	556
2018-19	27,339	86,602	9,909	4,682	487
2019-20	33,585	80,121	10,815	4,152	514

2020-21	28,543	87,847	9,346	3,323	505
2021-22	29,181	74,862	15,182	3,709	314

Literature Review:

Authors have conducted numerous research studies examining the SWOT analysis of policies implemented across various countries. These studies explore the strengths, weaknesses, opportunities, and threats linked to various policy initiatives. In Table 2, we present a refined review of the literature, focusing on studies that address this concern in depth.

Methodology:

SWOT analysis is a technique or guide that is used to estimate the reputation of any company based on its four components: strengths, weaknesses, opportunities, and threats. The first two of them, strengths and weaknesses, assess the internal factors, whereas the remaining two, opportunities and threats, explain outer factors [26][27][28]. SWOT analysis evaluates internal features, encompassing strengths and weaknesses, along with external aspects such as opportunities and threats. Two key points are involved in this analysis. One of them is used to solve SWOT factors and form a matrix. On the other hand, internal and external factors are formulated by the SWOT matrix in the second step [29]. Actually, the SWOT framework is designed for marketing and business analysis invention, but it can be adopted in other research fields also, for example, energy management [30]. Figure 2 illustrates all of the components of the SWOT analysis.

Figure 2. Components of SWOT analysis

This research utilizes SWOT analysis as a key tool to scrutinize the strengths, weaknesses, opportunities, and threats of AREP 2019 in Pakistan. The study aims to enhance strengths, address weaknesses, leverage opportunities, and mitigate the impact of threats associated with the AREP of 2019 in Pakistan. There are few modern techniques for example seminars can be organized in collaboration with researchers and stakeholders of energy; operators and officers; ministries and regulatory authorities; foreign and local investors; energy generation companies and consumers industries; distribution and transmission companies; private sectors and local governments; media and public to understand where the world is standing and where we are to cope all the energy related problems. There should be more than one session of the seminar in which all the components of SWOT, all the problems and solutions regarding energy, should be discussed. The predicted outcomes of the SWOT analysis and all other arguments should be taken into account by the governments and other responsible authorities. The SWOT factors were identified through a structured qualitative review of national energy policy documents, official government reports, and peer-reviewed literature related to Pakistan's energy sector. The initially identified factors were screened for relevance and consistency with the objectives of AREP 2019 and cross-validated through expert insights from energy-sector stakeholders. Analytical depth is ensured by systematically interpreting each SWOT dimension in relation to policy implementation, energy security, and system-level constraints, thereby providing a coherent and methodologically sound assessment rather than a descriptive listing of factors.

Table 2. Selected studies on SWOT analysis

References	Key findings
[31]	Sibtain et al. examine the utilization of hydropower through SWOT analysis in Pakistan. The strengths of hydropower are abundant potential and sustainability. The weaknesses draw attention to considerable capital cost, seasonal variations, reservoir degradation with the passage of time, and the requirement of a long project completion time. The opportunities are energy security, storage dams, unexploited potential, and global warming. Finally, the threats include fossil fuel dependence, shared water resources, and unclear and irregular energy policies. Although there are some issues in adopting hydropower for energy generation, it is still a cheap, secure, and clean source of energy.
[32]	The author adopts Interpretive Structural Modeling and SWOT analysis to assess the mechanism of developing renewable energy in Rwanda. This study proposes and evaluates 13 key strategies, of which four are given priority. The analysis brings to light the factors that affect the energy sector of the country. The stakeholders, investors, and policy-makers of the energy sector can understand opportunities and challenges through this analysis. The results show that seven strategies are capable of manipulating the renewable energy sector, such as promotion of awareness of energy, provision of policy support and incentives, exploitation of research and development activities, strengthening of institutional management, creation of favorable conditions to attract the private investors, strengthening of technological ability, and allocation of investment.
[33]	The policy makers want to produce maximum energy from renewable energy up to 2030 for the betterment of the energy and climate framework, but the target in the transport sector up to 2020 has not achieved in Europe. This research work describes the SWOT analysis along with the analytic hierarchy process (AHP) of green gas. The analysis shows that bio-methane has a sustainable potential to replace natural gas, but governments are responsible for market growth. SWOT-AHP analysis confirms that subsidies play essential roles in the biogas market. Further, new local small biogas plants are developed. The awareness and human behaviors are also important in this regard.
[34]	Kamran et al. proposed that a SWOT analysis can serve as a reference point, diagnosing the feasibility of the current scenario and providing a guide for future development in the renewable energy sector in Pakistan. The study's findings shed light on the socio-economic and environmental impacts of sustainable energy development through a thorough analysis of strengths, weaknesses, opportunities, and threats from a local perspective. Furthermore, given the current situation, there is a need for new strategies and policies to address the availability of RES to effectively manage the energy crisis and enhance sustainability in Pakistan.
[35]	To assess significant internal and external factors impacting renewable energy technologies, the author applies SWOT analysis in Sindh and Baluchistan, provinces of Pakistan. The Fuzzy Analytic Hierarchy Process (AHP) technique is employed to address environmental, economic, socio-political, and technical considerations. The final model discusses essential criteria, substantial potential, and rankings of three AERs - wind, solar, and biomass. These insights offer the government viable options to bolster energy security and alleviate the energy crisis for sustainable development.
[26]	The author conducts a SWOT analysis of Pakistan's National Power Policy 2013, addressing current challenges and future energy needs. The policy analysis offers solutions such as harnessing local resources, optimizing energy mix systems, increasing power production from RESs, utilizing cost-effective fuels for electricity generation, upgrading existing

	Transmission and Distribution (T&D) systems, and restructuring the industry. This study provides a roadmap for the government's future initiatives. Additionally, it emphasizes how strengthening human and institutional capacities contributes to the development of the country's energy sector.
[36]	Azubuike et. al presents SWOT analysis for the development of shale gas to investigate the legal issues and key policies in Algeria. The dependence on natural gas can decline the country's economy. Data from different reports, policies, articels and books are used to examine the environmental concerns of shale gas. This analysis identifies the required course of action for shale gas development. The key factors of analysis, such as unattractive government policies, terrorism, community conflict, challenges of infrastructure and funding, and the absence of significant technologies, are barriers to policy development. The analysis gives the solution of abovementioned issues.
[37]	In this research study, the author emphasizes the extensive use of SWOT analysis for strategic forecasting within academia and industries. SWOT analysis is instrumental in identifying and addressing the strengths and weaknesses inherent in the current energy system. By exploring opportunities, the country can capitalize on potential avenues for development, while also signaling potential threats that might impede the attainment of set targets. This SWOT analysis serves as a valuable tool in proposing procedures and actions for inclusion in the strategic roadmap.
[38]	To gain expertise in clean energy technology in the international RE market, the author performs a SWOT analysis of advanced RE policies and technologies of three countries: South Korea, Taiwan, and Japan, members of the Asia Pacific Economic Cooperation. The research work identifies the capability of extra RE available in these countries, highlights the prerequisite collaboration to strengthen their RE sectors, addresses environmental challenges and energy security, and struggles in the international RE market in the post-Fukushima era. However, offshore wind power plants, for South Korea and Japan, are particularly advantageous. The RE technology in Taiwan can be improved by transferring technology from Japan.
[39]	This research study performs the SWOT analysis of climate and energy policies between provincial and federal strategies in Canada. Canada is abundant in natural resources and RESs, but the author highlights the unequal distribution of these resources across different parts of the country. This SWOT analysis depicts the lack of consistency in Canadian policies between regional and federal strategies; particularly, there is no long-term plan for the management of these sustainable sources. In 2011, Canada withdrew from the American climate policy to reduce GHG emission targets. In addition, there are coordination issues of provisional and federal public acceptability limitations and environmental regulations.

SWOT Analysis of AREP 2019:

In 2019, the GoP introduced a new policy centered around renewable and alternative energy sources. This policy aims to encourage the adoption and utilization of sustainable and environmentally friendly energy options in the country. This initiative signifies a noteworthy step towards promoting sustainable and alternative energy solutions. Figure 3 visually presents the policy's main objectives, challenges, and proposed solutions.

Main Objectives	Protection of environment by use of "green" energy Low price power generation with limitations Fast track and transparent development power projects Utilization of local resources Encourage investors
Challenges	Use of heavily fossil fuels in energy-mix Expensive energy generation Poor infrastructure of existing power distribution system Transmission and Distribution losses Achieve energy security, affordability of electricity, availability for all, environmental protection, sustainable development, social equity and mitigation of climate
Solutions	Use both conventional renewable energy sources as well as alternative technologies Significant changes in terms of deployment, technological advancements and cost competitiveness. Up gradation of the transmission infrastructure Introduced strong economic incentives to attract invest and remove barriers to project implementation A regulatory authority like NEPRA should regulate the changes and investors

Figure 3. Review of AREP 2019 [40]

The author [41] explains the terms strengths, weaknesses, opportunities, and threats well. First of all, the term "strengths" refers to available resources, which highlight the performance. On the contrary, "weaknesses" stand for flaws that are responsible to limits the efficiency, benefits, and economic resources. Next, the external changes represent "opportunities" that become the reason for supplementary progress. On the other hand, threats stand for external factors, which increase problems. Figure 4 illustrates the components of SWOT (Strengths, Weaknesses, Opportunities, and Threats) for the AREP 2019 of Pakistan.

Strengths:

The strengths of the AREP 2019 of Pakistan are as follows;

Untapped Potential of RESs:

The indigenous, cleanest, and most cost-effective energy source readily available in Pakistan is hydropower, with an available potential of 60,159 MW. Additionally, the technical potential for solar power is estimated at 149 GW, wind power at 346,000 MW, and annual bio-fuel production at 50 million tons in the country [17]. Pakistan heavily relies on fossil fuels for electricity generation, posing a potential threat to the country's environment [3] and economy but now this policy give new horizons for power generation to expand energy generation on new types of projects including ocean /tidal wave energy, geothermal, biomass, biogas, energy from waste, solar, storage technologies, hydrogen or synthetic gas and wind. Hence, the country eliminates the necessity to import fossil fuels for power generation. In the policy, it is mentioned that for the protection of the environment, to keep it green overall energy mix is used for power generation, 25% of the energy mix depends on renewable energy up to 2025, and 30% up to 2030. Due to the huge energy potential, private investors are encouraged to take part in energy generation [40].

Project Development Options:

With the collaboration of the National Transmission and Dispatch Company (NTDC) in expanding the transmission system, the GoP can endorse and allocate projects that are prepared to supply electricity to distribution companies (DISCOs) or the national

grid. A competitive and transparent process is implemented to attain high efficiency in three modes.

In competitive binding, GoP shall announce routinely the tenders involving single or emerging multiple technologies, but the feasibility study of the project is not important. The binding documents should include load centers, cost-effective interconnection availability, distribution, and resource mapping.

According to the laws of Pakistan, the government-to-government projects may be announced under government-to-government frameworks.

Where a feasibility study is required, unsolicited projects will be introduced according to the third mode.

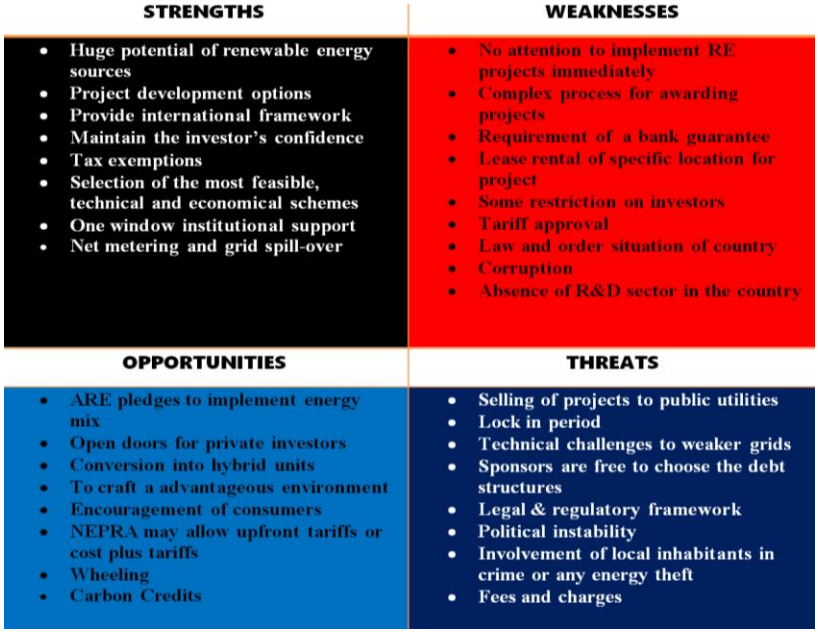

Figure 4. SWOT analysis of AREP 2019 of Pakistan [40]

The Provisional Governments are also allowed to institute policies regarding power projects, place power transmission lines, distribution systems, and even set tariffs under Article 157 of the Constitution of Pakistan.

An additional committee at the Federal Government will review the project's proposals with the liaison of the Provisional Government to implement such projects for power generation [40]. The following flowchart can help to understand the steps involved to facilitate the private investors and sponsors in Figure 5. The flow-of-study diagram illustrates the sequential research process, beginning with policy document review and literature analysis, followed by identification and validation of SWOT factors, and culminating in analytical interpretation and policy recommendations. Each stage represents a distinct methodological step that ensures logical progression from data collection to policy-oriented insights. This structured flow enhances methodological transparency and analytical coherence of the study.

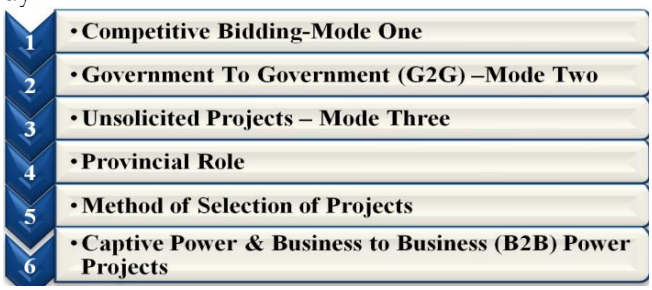

Figure 5. Steps involved facilitating the private investors and sponsors [40]

Weaknesses:

The weaknesses of AREP 2019 are briefly discussed below. Eliminating these weaknesses is crucial for achieving the desired goals.

No Attention to Implement RE Projects Immediately:

As of 2020, Pakistan faces an electricity shortfall of 38.36 TWh, a gap that could be addressed by installing wind energy generation capacity of 10.4 GW and solar power generation capacity of 882 MW [42]. Moreover, Pakistan possesses significant potential in RESs to overcome energy economic challenges [43], but it is mentioned in the policy that only 20% of the total capacity of power generation will depend upon ARE technologies by 2025. It is a very small amount of energy generation, so the government intends to generate maximum energy from non-conventional energy sources. As there are more options available in terms of RESs instead of non-RESs, as shown in Figure 6. So, the government should take necessary action to install new renewable energy power projects immediately.

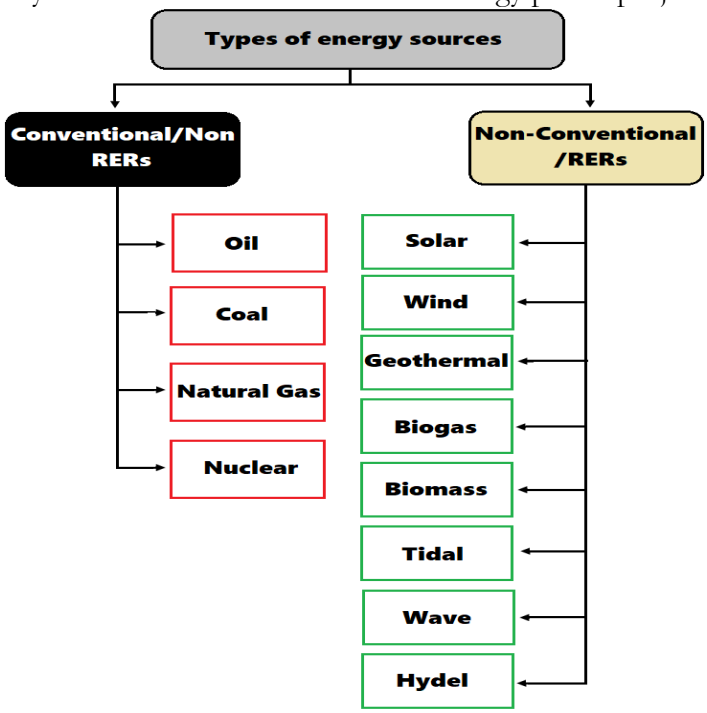

Figure 6. Types of energy sources

Substantial Disparity between Demand and Supply:

In the demand-supply of electricity, electricity demand always leads the electricity supply. There was a deficit of 1318 MW, 5716 MW, 5201 MW, and 5000 MW in the years 2005, 2010, 2015, and 2019, respectively [43]. There are 8% power losses in the existing power generation and utilization [42], which could exacerbate the demand-supply gap significantly. Figure 7 presents the demand-supply disparity in Pakistan spanning from 2015 to 2019. For the development and betterment of the country, the demand-supply gap should be removed. All types of renewable energies are used to generate electricity to overcome the demand-supply gap.

Complex Process for Awarding Projects:

In the first instance, a subcommittee under ADEB will examine the proposals of the feasible projects of the qualified investors. After consultation with AEDB, NTDC, and Central Power Procurement Agency (Guarantee) Limited, the AEDB will issue an LOI to the investor with a bank guarantee. In the second stage, after approval of the feasibility study, a LOS will be issued to a sponsor with the consultation of the National Electric Power Regulatory Authority (NEPRA) and the Engineering, Procurement and Construction,

who set the tariff and give a generation license, respectively [40]. It is the duty of the GoP to provide a smooth path for the encouragement of private investors, so they can follow an easy way to implement the new projects.

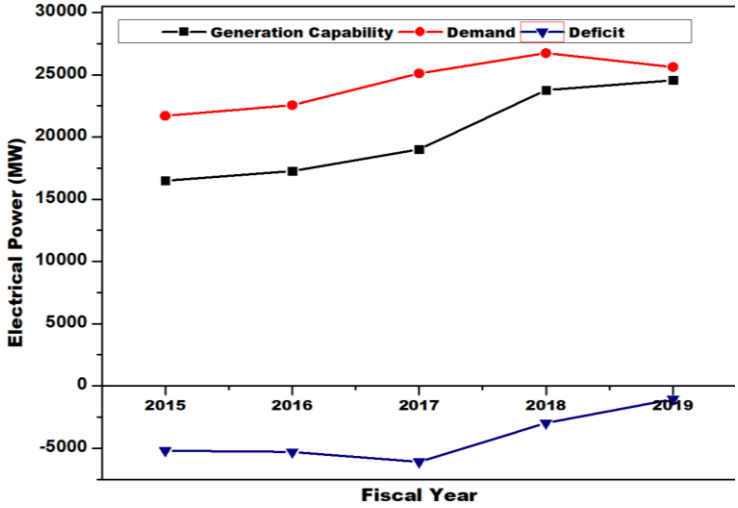

Figure 7. Demand-supply gap of electricity from 2015 to 2019 in Pakistan [9]

Lease Rental of Specific Location for Project:

To add new renewable energy projects, AEDB, on behalf of all provinces of Pakistan, will allocate the land to the sponsors [40]. To execute new power generation projects aimed at mitigating the energy demand-supply gap, the government should give a piece of land for a continual flow of electricity to customers via the grid without any guarantee, rent, or lease. The government must attract investors to remove all unnecessary hurdles and obstacles from them, so they are ready to invest in such a developing country.

Opportunities:

The opportunities of AREP 2019 of Pakistan are as follows;

ARE Pledges to Implement Energy Mix and Conversion into Hybrid Units:

One of the main promises in this policy of the government is to implement an energy mix and convert the existing projects into hybrid units. We should move towards green energy to protect the environment because the entropy of the environment is increasing day by day. The conversion of current wind and solar power projects into hybrid units and any other technology that may not be acknowledged in this policy shall be considered with the passage of time [40].

Encouragement of Private Investors, Sponsors, and Consumers:

The government gives an exemption to the electricity sellers from corporate income tax for attracting. Equity, sales tax on power plant, tools, and machinery for sponsors, and payment of Zakat for non-residents and non-Muslims are also exempted. One more advantage for the investors is that they are free to decide about the payment of installments of the loan to banks. For the promotion of the energy sector, if the Business-to-Business projects are selling electricity directly to the customers or consumers who have their own power generation system below 5 MW, all of the above categories are free to get approval, No Objection Certificate (NOC), or any generation license from AEDB, NEPRA, and DISCO [40].

Legal & Regulatory Framework:

The executive authority in the power sector under the GoP is the Ministry of Energy (Power Division), responsible for formulating and presenting new policies. Within the power division, a robust platform, structure, and legal and regulatory framework are in place. This framework includes NEPRA, responsible for generation, distribution, and transmission; Bahria Town; Karachi Electric; DISCOs, responsible for providing electricity distribution to

consumers; NTDCL, responsible for transmission; the Central Power Procurement Agency (Guarantee) Limited; thermal generation companies (GENCOs), responsible for the control and management of electricity; WAPDA-Hydel Wing, and independent power producers, responsible for the generation of electricity [40]. There is a proper system to attract and support the private investors, sponsors, and customers. The interrelation of all agencies is shown in Figure 8.

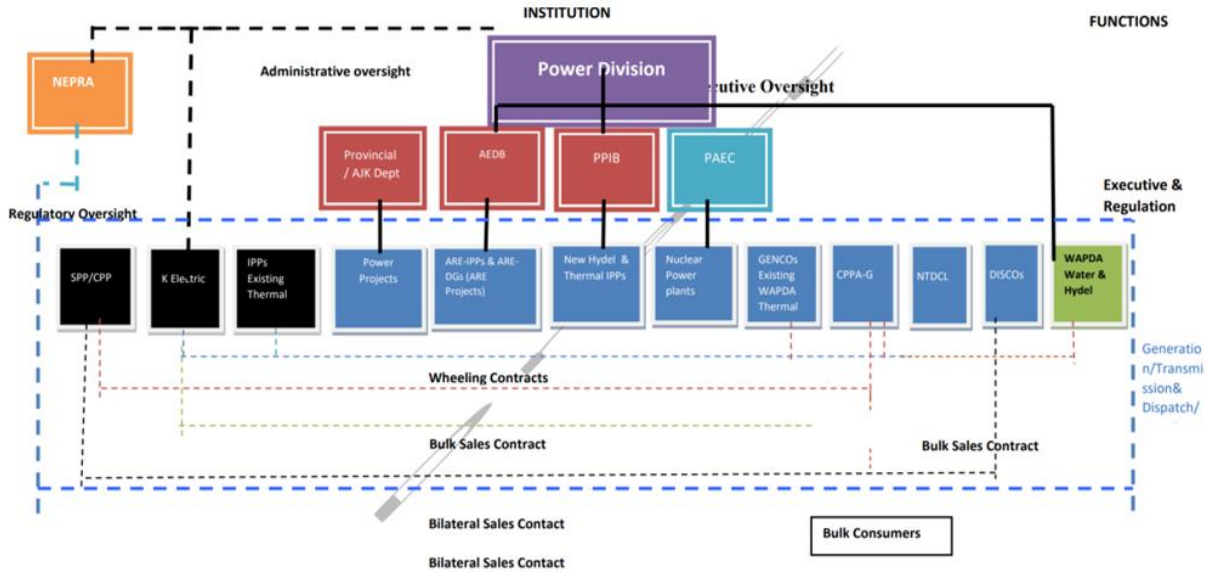

Figure 8. The inter-relation of all agencies [40]

Wheeling:

To transport the electric power from the power generation projects to the buyers, the investors can utilize the transmission lines and grids of the utilities at wheeling charges. NEPRA will govern these wheeling rules and can revise with time to time [40].

Carbon Credits:

As future energy demand will rise up to 25 billion tons of oil equivalent globally, with this increase, the emission of carbon dioxide CO2 would increase to 75 gigatons in the next few decades, and this abrupt change will ultimately having bad impact on the climate. The good initiatives are revolutionary technologies and RESs to survive with this problem [44]. The AEDB introduces a program to educate and assist ARE project developers in purchasing and selling carbon credits in the international market. The revenue generated from this scheme will be exempt from duties under the Kyoto Protocol and Paris Agreement [40].

Threats:

The threats of AREP 2019 of Pakistan are as follows;

Lock-in Period:

A hurdle faced by the private investors is the lock-in period under this policy. The lock-in period for the electricity project is 5 years from the date of commissioning, which means that the owner of the power project cannot sell the project below 51 % without permission from AEBD [40]. The rule should be that anyone can construct the project, and the owner can sell the project directly to the utility or any other interested third party for the sake of encouragement.

Technical Challenges to Weaker Grids:

In developing countries, the power interruption is a characteristic feature of national grids [45]. There are some technological issues with weaker grids in Pakistan due to variable renewable energy projects. The main problem is that due to surges in voltage or frequency at one location, the grid becomes unstable. Two main solutions are also present to tackle the

issues. Firstly, grids are supported by extra equipment and the latest technologies to face the abrupt changes. Secondly, before integration of projects to grids, the NTDC play important role in improving grids to improve grids make generation plans [40].

Political Instability and Corruption:

The foreign sponsors are not ready to invest in Pakistan due to political instability, law and order situation, bureaucracy and political involvement, exodus problems, corruption, and a weaker system to manage projects. Many projects initiated by the private investors were victims of the interference of many departments. Also concern departments were unable to perform their work well for developing projects, and some investors complained about the contradiction between the ground realities and international standards [46]. There are many political and community restrictions on land to initiate solar power plants in Pakistan. Although many lands, which are not suitable for agricultural purposes, are available to establish the solar power plants [47]. In South Asia, the primary impediments to the realization of regional energy projects are likely the political challenges. The essential issues, for example, technical, economic restraints and bureaucratic incompetence should also be under consideration [48]. The Political instability and corruption of almost all departments in Pakistan are a big threat to the energy economy, energy sustainability, energy security, and installations of new power projects. The framework of departments is unreliable due to the involvement of politicians and bureaucracy, and there is a need for strong work on this issue.

Involvement of Local Inhabitants in Crime or Any Energy Theft:

Electricity theft remains a significant issue in developing countries, such as Pakistan [49]. The huge financial losses incurred by the electricity utilities are due to electricity theft. Many consumers take advantage of the electricity utility without paying bills. It is a big challenge to detect deceitful customers who are involved in energy theft [50]. Overall theft of electricity has a considerable shock on the grids, which produces some non-technical losses that are responsible for degrading the quality, to minimize the system efficiency and profit from the utility [51]. In Pakistan, it is difficult to sort out such people because some utility employees may also be part of this crime; they follow some unofficial sources in terms of getting money or precious gifts, and allow local people to do activities like meter tampering or line tapping. A lot of work is required to change the behavior of the local inhabitants. The government should play an important role in punishing such criminal employees and people, and use modern techniques to prevent this type of crime.

Charges:

It is mentioned clearly in the policy that the AEDB may revise the processing and maintenance charges from time to time [40]. It is a drawback of the policy that the charges will vary from time to time. If the sponsors think about these things, then it may happen that no investors will implement such fruitful projects in the country.

Suggestions and Recommendations for Future Roadmap:

Researchers have been actively engaged in tackling the issue of electricity generation. The author highlights that although Pakistan currently utilizes a relatively smaller proportion of RESs like solar, wind, biomass, and hydro for generating power, the country possesses abundant solar, hydro, wind, and biomass energy potentials that attract both local and foreign investors to establish such power plants each year. These renewable energy projects hold the potential to diminish Pakistan's impact on global GHG emissions. The strength of the policy is bolstered by factors such as the availability of diverse energy sources, environmental friendliness, the appeal to private investors, and future roadmaps. However, challenges such as an underdeveloped system, significant capital investment requirements, environmental hazards, and technological issues still need to be addressed. To achieve sustainable development, key opportunities lie in micro installations, leveraging the vast energy potential, off-grid energy generation, and upgrading existing systems. On the other

hand, it is essential to address threats such as the lack of grid connection, limitations of existing transmission systems, unattractive policies, and competition from other energy resources [34]. Abas et al. [11] a feasibility study for a 100 MW solar PV power plant in Pakistan, proposing it as a potential solution to address the electricity generation problem.

The study comprises a thorough technical and economic analysis of the proposed solar power plant, offering valuable insights into the practical aspects of initiation. This includes initial costs, projected payback period, and other advantages associated with generating affordable electricity through solar energy. The study serves as a valuable resource for potential sponsors and the government, providing real-time ideas and recommendations for the commissioning of such a power plant. Another solution to alleviate the energy crisis in the country involves the implementation of net-zero energy buildings. These buildings aim to meet their on-site energy demand by utilizing RESs. A contrast between a traditional and a net-zero energy structure highlights the advantages of the latter. In the net-zero energy dwelling scenarios, a renewable energy system is employed to generate energy, meeting the building's energy needs. Any excess energy generated can be fed back to the utility using net metering. Alternatively, the suggested concept integrates on-site RESs for self-sufficient electrical power generation within the structure. Extra energy can then be distributed to neighboring residences or sold to the utility. To evaluate the effectiveness of the proposed system, simulations are conducted on an hourly basis throughout the year using TRNSYS simulation software, with a specific focus on sub-zero temperature areas. This analysis enables a comprehensive evaluation of the system's feasibility and effectiveness [52].

The authors addressed the issues encountered by the energy sector in Pakistan and proposed significant solutions. This study examines the existing power production systems from two perspectives. Firstly, it emphasizes maximizing the efficiency of the available systems. Secondly, it analyzes 70% of the energy generated by the existing power plants. The study further explores a scenario that identifies the optimal mix of power generation, aiming to reduce the overall cost of power generation. Additionally, the government takes measures to compensate for the subsidies provided, reducing the burden on electricity-generating and oil supply companies. This approach also contributes to the reduction of circular debt, which acts as a barrier between these entities. While the proposed model may increase the government's subsidy expenditure, it simultaneously works towards minimizing power generation costs and further decreasing circular debt [53]. The research work [42] explored the concept of a wind and solar power mix, wherein 95% of the energy generation is derived from wind power and 5% from solar power. The study illustrates that this combination minimizes power losses to negligible levels. The proposed idea was modeled using weather data to calculate renewable energy generation, conventional power production, and electricity demand, utilizing consumption data from the year 2016. By implementing such a power generation mix, including the integration of the cooling sector, Pakistan can effectively address its energy crisis. This approach offers a sustainable solution that harnesses the potential of wind and solar energy to meet the country's power needs. Here are some other proposed future roadmaps to tackle this matter:

Investing in research and development efforts to advance technologies related to electricity generation, energy storage systems, and grid integration, aiming for more sustainable and efficient solutions. Exploring and implementing a diverse range of energy sources, including renewable energy (solar, hydro, wind), nuclear power, and clean technologies, in the energy-mix to diminish fossil fuel dependence and reduce GHG emissions. Promoting and adopting energy-efficient technologies and practices in different sectors, including residential buildings, industries, and transportation, to optimize energy consumption and lessen waste.

Implementing supportive policies and regulations, along with offering incentives like feed-in tariffs, tax credits, and subsidies, to promote the development and adoption of sustainable energy solutions. Upgrading and modernizing the electricity grid infrastructure to improve its reliability, efficiency, and ability to integrate RESs, as well as enabling smart grid technologies for monitoring and managing electricity distribution. Collaborating with other organizations, experts, and countries to share knowledge, best practices, and technological advancements in the field of electricity generation, fostering global efforts to tackle the issue collectively.

Conducting educational programs and awareness campaigns for the promotion of energy conservation, renewable energy options, and responsible energy consumption among the general public, businesses, and policymakers. By implementing these suggestions, substantial progress is expected in overcoming challenges and enhancing the sustainability and reliability of electricity generation in the near future. Although the results are organized using the SWOT framework, the analysis goes beyond descriptive categorization by systematically interpreting each factor in relation to policy implementation effectiveness, energy security, and institutional constraints. The findings analytically link internal strengths and weaknesses with external opportunities and threats to derive strategic implications and actionable policy insights, thereby providing a coherent and in-depth evaluation rather than a purely descriptive account. Similar to the findings of [32] for Rwanda, this study identifies institutional coordination and policy incentives as critical enablers for renewable energy deployment, while procedural complexity and financing barriers remain key weaknesses. Likewise, in line with [34] for Pakistan and comparable developing economies, the present analysis highlights that despite strong renewable potential, ineffective implementation and grid limitations continue to constrain policy outcomes [54]. The practical feasibility of the proposed suggestions is assessed by aligning them with Pakistan's existing institutional capacity, regulatory framework, grid infrastructure, and investment environment.

Conclusion:

Since 2000, the Government of Pakistan has introduced only four energy policies in 2006, 2013, 2015, and 2019. However, the lack of implementation of these policies has resulted in electricity blackouts in the country. To gain a comprehensive understanding of the SWOT of the Alternative and Renewable Energy Policy 2019 of Pakistan, this research work proves to be invaluable. The study aims to identify the strengths that can enhance the policy's effectiveness, address weaknesses, capitalize on opportunities, and mitigate potential threats related to alternative and renewable energy as outlined in the 2019 policy. It sheds light on the policy's primary objectives, challenges, and proposed solutions, providing a foundation for understanding future energy issues, energy security, energy management, and the energy crisis in the country. By exploring this research work, Pakistan can better tackle existing and future energy-related problems, fostering a path towards energy prosperity and development. The study emphasizes the economic burden of relying heavily on fossil fuel-based energy generation and highlights the immense potential of renewable and alternative energy sources. It also discusses the significance of renewable and alternative energy, modern research techniques employed by stakeholders, roadmaps for cost-effective electricity generation, environmentally friendly projects, and the need for upgrading the energy mix. Additionally, the study suggests solutions that individuals within the country can adopt to contribute to the overall energy landscape. It provides a roadmap for attracting private investors, presenting new energy strategies, and outlining future energy plans for the government. It stresses the importance of not only periodically announcing power policies but also ensuring proper implementation to steer towards the right energy horizons.

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