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Analyzing Pakistan's Renewable Energy Potential: A Review of the Country's Energy Policy, Its Challenges, and Recommendations

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Abstract: Pakistan's dependence on imported fuels has led to a massive electrical shortfall, stifling the country's socioeconomic growth. Pakistan's energy gap is between 5000 and 8000 megawatts (MW), with a 6–8% yearly growth predicted, therefore, it needs more sustainable and renewable energy sources. Pakistan uses solar, wind, hydropower, and biomass for renewable energy. Pakistan needs cheap energy to support its economic growth. Most of the world's energy is currently conventionally produced. The objective of this research is to analyze the opportunities that are afforded by renewable energy sources as well as the role that the government plays in the process of policy formulation. An examination of qualitative data from research works, journals, and government annual performance reports is presented. This study investigates renewable energy sources and government policy. According to the study, renewable energy resources are abundant. The renewable energy plan has no effect on real implementation. This research paper examines electricity restrictions, the transition to renewable energy sources, and Pakistan's renewable energy policy difficulties. After analyzing the nation's renewable energy potential, practical implications were made to promote it, for example 1710-megawatt wind installations. There are currently 217-megawatt biogas power stations being developed. Accelerating the energy transition to the nation's future energy perspectives is a priority for sustainable development.

Keywords: renewable energy; energy perspective; readiness assessment; power policies and frameworks

Citation: Xin, Y.; Bin Dost, M.K.; Akram, H.; Watto, W.A. Analyzing Pakistan's Renewable Energy Potential: A Review of the Country's Energy Policy, Its Challenges, and Recommendations. *Sustainability* **2022**, *14*, 16123. https://doi.org/10.3390/su142316123

Academic Editors: Yu Hao, Haitao Wu, Muhammad Irfan and Xiaodong Yang

Received: 26 August 2022
Accepted: 21 November 2022
Published: 2 December 2022

1. Introduction

Pakistan's massive power shortfall has become a major hindrance to the country's overall socioeconomic advancement as a direct result of the country's almost complete reliance on fuel import. As a result of this situation, local gasoline costs are far higher than they should be, and the construction of new industrial parks is moving at a much slower rate. It is imperative to reduce carbon emissions along with energy prices, by maximizing energy security, dependability, and making improvements to the infrastructure. The United Nations General Assembly (UNGA) established a framework for the earth's sustainable development objectives in the year 2015. These goals were outlined in the 2030 Agenda for Sustainable Development Goals (SDGs). The goals included poverty reduction, adequate resources and justice, and environmental and energy protection for future generations. The use of renewable sources of power was critical to the formulation of the strategy to ensure that everyone has reliable, low-cost, and uncomplicated access to the energy they need [1]. The goal set by the General Assembly of the United Nations is to meet future energy needs while doing as little damage as possible to the environment. One way to do this is to use renewable energy sources.

Renewable energy technology has attained commercial adoption and become economically competitive with conventional energy. Renewable energy is easy to deploy, economical, and environmentally benign [2]. In 2016, Europe's renewable energy usage grew by 17%, which was double from 2004 (8.5%). The EU's 2020 renewable energy policy called for 20% renewable energy. Malta and Luxembourg have the lowest renewable energy proportion in the EU. The EU implemented the energy transition strategy to increase sustainability, security, and competitiveness and to lead in renewable energy. According to BP's 2018 energy projection, renewable energy will expand by 2040, providing 14% of the world's primary energy [3].

Current trends show expanding importance of renewable and wind energy in satisfying future energy requirements. The Worldwide Wind Energy Council estimates that global wind energy will reach 743 GW by 2020 (GWEC). The year 2020 was the biggest year in wind-energy history, with 93 GW of new installed capacity, a 53% increase from the previous year. China and the United States of America dominated the wind energy industry in 2020, with the installed capacity up 75%. It retained 1.1 million tons of CO_2 worldwide, similar to South America's emissions [4].

The current practices are not enough to achieve neutrality until the middle of the century [5]. According to the US Energy Information Administration, 80% of energy comes from fossil fuels, 11% from nuclear energy, and 8% from renewable methods of energy. The USA energy strategy emphasized various suppliers, infrastructural dependability, affordable energy pricing, and environmentally sustainable energy generation [6].

In the previous research, a review on renewable energy strategies for promoting renewable energy shows the history and development of five nations: The USA, Germany, the UK, Denmark, and China. EU requirements required the UK to produce 20% of its energy from renewable sources by 2020 [7,8]. Denmark's history of using renewable energy is extensive, where wind energy is widely used for heating and electricity. Wind energy technology was implemented under the renewable energy program in rural regions, and offshore wind energy production is on the way [9].

China has installed renewable energy technology. China's wind energy system ranked first in the world. Energy policies advocate for regulations and measures, whereby rewards and punishments are their most straightforward measures. Many experts and government officials are interested in China's feed-in tariff and carbon tax [10].

India is embracing renewable energy to boost its energy mix. India plans to obtain 225 GW of renewable energy by 2022 [11]. Renewable energy capability, policy, and problems are detailed in [12]. A lack of government legislation, international bans, and public knowledge are the primary barriers to renewable energy in Indian region [13]. Saudi Arabia's renewable energy plans have similar issues [14]. The challenge of ensuring energy is especially difficult for Jordan, which struggles from fossil resource shortages and regional instability [15]. The majority of Jordan's energy comes from fossil fuels. The domestic demand for electricity is rising at a steady rate, while the nation imports approximately 94% of its energy supply. In addition, this makes the Jordanian energy industry especially vulnerable to regional wars. Previously, instability in the region has also caused intermittent supply and price fluctuations (as was the case with liquefied gas imports from Egypt, which have been disrupted since 2011) and has induced the government to rethink the solution for their energy policy, exploring the viability of alternative energy sources such as shale oil and nuclear energy and testing new international agreements [16].

Qatar's National Vision 2030 similarly emphasizes renewable energy. Qatar will produce 20% of its solar energy and reduce its reliance on fossil fuels.

Bahrain Vision 2030 says that the nation will create 280 megawatts of renewable energy by 2025 and 710 MW by 2035. Energy is crucial for national growth [17]. Pakistan is a developing country that installs conventional power plants to suit its energy needs. Fuel-based energy is a fallacy in Pakistan's power sector industry. Experts heavily rely on traditional methods. Conventional power plants have expensive installation and per-kWh energy costs. The abrupt rise in oil prices cripples Pakistan's energy sector [18]. Figure 1

shows fluctuations of oil prices in Pakistan from 2018 to 2020. Since 1991, oil imports have risen 3.8% annually. In 2016, 74 MTOE of fossil fuels were used, compared to 28.6 MTOE in 1990 [19]. Figure 2 shows Pakistan's GDP from 2001 to 2020.

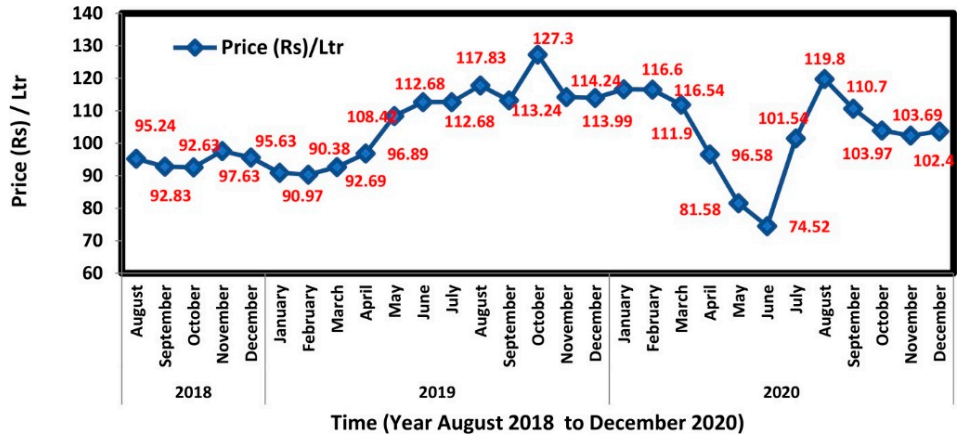

Figure 1. Oil price fluctuations in Pakistan from August 2018 to December 2020.

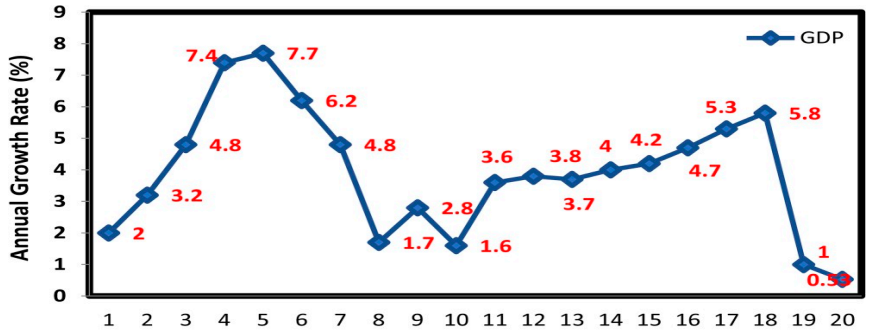

Figure 2. Annual growth rate product of Pakistan from 2001 to 2021.

Natural gas is an indigenous, cost-effective energy source. However, the conversion of power plants to natural gas, the establishment of CNG stations, and the transition to basic fuel for businesses greatly influence the industry. This has led to supply–demand fluctuations and load shedding. Oil (34.2%), natural gas (41.2%), LNG import (3.3%), LPG (1.2%), coal (6.7%), hydroelectricity (11.2%), nuclear (1.5%), and renewable (0.5%) provided the most energy in 2015–2016. Energy use grew by 8% annually. During the same period, more than 111,300 GWh of power was produced. Thermal supplied 63.4%, hydro 31.1%, nuclear 4.1%, and renewable 1.4%. However, consumption rose from 85,820 to 90,430 GWh [20,21]. The commercial sector grew by 10.5%, other sectors by 9.7%, and bulk supplies by 7.7% [22].

As observed in Figures 3 and 4, Pakistan's energy consumption trends have illustrated the shortage in energy from 2011 to 2016 [23]. The data show that the energy deficit between 2011 and 2016 fluctuated from 5100 to 7900 megawatts. Figure 3 displays Pakistan's energy resources, comprising imported fuel and locally generated energy. In addition, this map illustrates the top energy-consuming industries. A thousand tons of oil equivalents (TOEs) is the unit of measurement. Oil and natural gas dominate Pakistan's energy mix. Figure 3 displays the country's energy condition for 2019–2020.

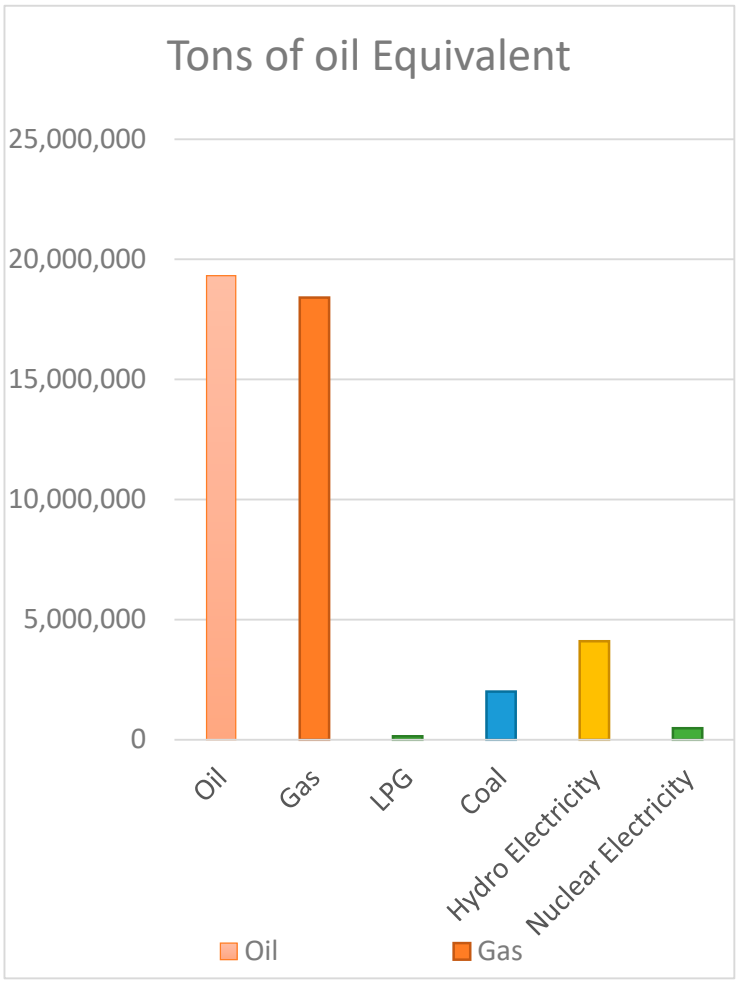

Figure 3. Energy scenario of Pakistan.

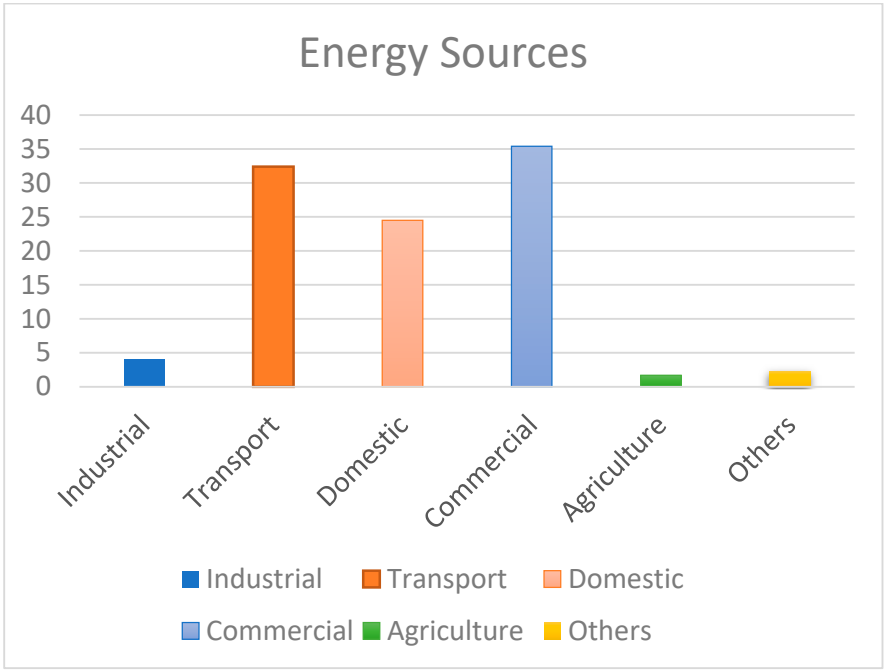

Figure 4. Sector-wise consumption (%) of energy sources.

Similarly, Figure 4 displays the energy resource consumption patterns of different economic sectors, with industrial and transportation sectors falling far behind. However, the housing sector ranks third in terms of energy resource utilization. A total of 15,920 TOEs were utilized by the industrial sector, while the home sector spent 15,287 TOEs. A breakdown of energy usage by industry can be seen in Figure 3.

1.1. Problem Statements

An analysis of Pakistan's energy market, including a discussion of its consumption trends, is performed to analyze the aim of the government of Pakistan, energy policies, and the establishment of authorized bodies, and the role of these bodies in distribution. Pakistan has a significant electricity deficit, which has proven a significant barrier to the country's socioeconomic development. This is a direct result of Pakistan's reliance on energy imports from other states [24]. An evaluation of renewable energy resources has been conducted in accordance with the potential of renewable resources in the various provinces. Renewable energy has attained profitable adoption and become economically competitive with conventional energy [1]. Pakistan is fortunate to have access to a diverse range of different energy sources. It is not impossible to generate power by utilizing the natural resources of the planet [25]. In conclusion, an analysis of the difficulties that are now being experienced by the exploitation of renewable energy resources, as well as suggestions for the expansion of renewable energy in Pakistan, is presented here.

1.2. Significance of the Study

This study's significance is to conduct an in-depth analysis of the current state of renewable energy resources, with particular attention paid to the generation of electricity from renewable sources, the evolution of energy policy over time, the difficulties encountered by the energy sector, and finally, the formulation of some potential solutions to this issue in Pakistan. An extensive study on numerous renewable energy businesses, including Pakistan, has been performed. Although Pakistan's previous energy policies have concentrated on the role of private investors, each problem directly influences Pakistan's energy industry. This research paper highlights the significance of the energy mix and provides information that might assist policymakers in rethinking their approach to it. On the other hand, the prospective energy assessment showed some holes in the system. Other important considerations include integrated energy planning, accomplishing the AEDB's goals, establishing a clear boundary between the most appropriate site, constraints on grid and transmission networks, and the role of private investment in infrastructure development. Solving the public policy problems focuses on identifying and addressing the difficulties brought to light.

1.3. Objective of the Study

The objective of this research is to analyze the opportunities that are afforded by renewable energy sources as well as the role that the government plays in the process of policy formulation. However, the strategy set for renewable energy will not in any way affect the actual deployment of renewable energy. This is a disappointing fact due to power laws, the shift to renewable energy sources, and the issues Pakistan's renewable energy strategy is presently experiencing, and this study will provide additional in-depth information.

2. Methodology

This study was conducted by analyzing qualitative data from a number of sources, including research works, journals, government annual performance reports, publications, books, and newspapers. This analysis served as the methodology for performing this research investigation. Figure 5 depicts the methodology used in this study to evaluate the prospective renewable energy resources that may be identified in Pakistan.

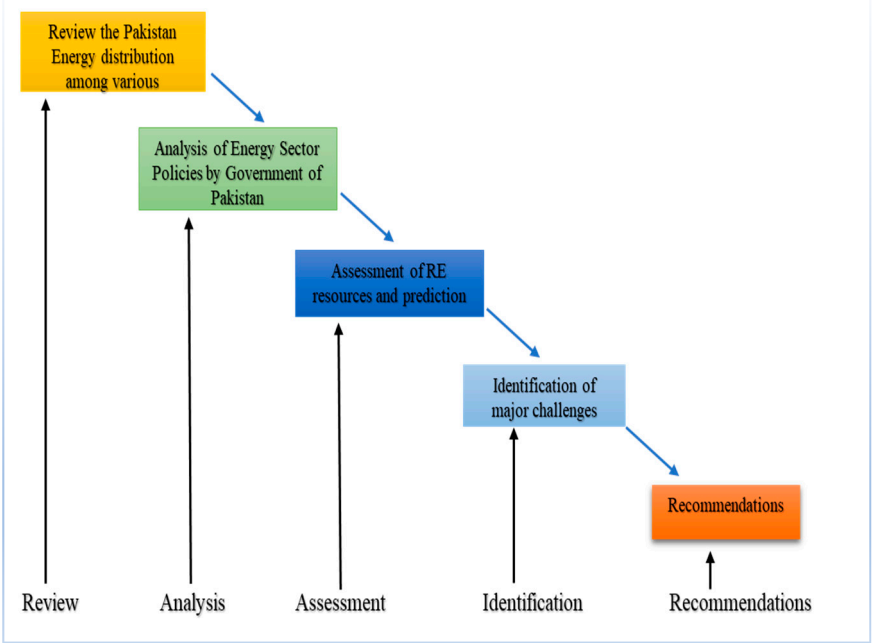

Figure 5. Methodology.

Method mapping is one of the most important contributions to this study, as it helps to detect potential flaws and thriving regions of Pakistan's renewable energy industry. A comprehensive examination of renewable energy policy in particular and energy policies in general can provide the most relevant knowledge. This study began with their roots, constitutional framework, structural processes between the provinces and federalism, and participation in the formulation of energy policy. In this phase of the study, the potential renewable energy resources within each province were evaluated. The evaluation of the preceding section lays the groundwork for the defining phase, which in turn lays the groundwork for the subsequent suggestions. It is possible that Pakistan's government would be able to develop renewable energy successfully if they gave the recognized areas the time they deserved.

2.1. National Power Policy 2013

The RNC presented a national energy policy in 2013 to meet current and future needs. Since 2011, the government has had a 7900-megawatt energy shortfall. This unlocked Pandora's box in the energy industry, and the government focused on meeting demand. Visions, issues, goals, and policy proposals were crucial. The energy plan minimized supply–demand mismatch, ensured appropriate pricing, boosted transmission and distribution efficiency, and sped up ministerial decision-making. This load-shedding plan involves generation, distribution, transmission, and government.

2.2. The Power Policy of 2015

The supply–demand imbalance was a problem in 2010 and beyond. The government needs to replace previous limits with a new energy plan. The GOP's 2015 electrical strategy addresses the supply–demand mismatch. New legislation requires IPPs to encourage energy-related activities. Using low-cost energy-generating technology, indigenous energy resources, and fair stakeholder involvement, the GOP protected the environment. Hydroelectric and thermal projects receive priority for private investment and public–private partnerships. The GOP founded PPIB and its provincial counterparts, and the GOP's promises to local and foreign investors helped the electrical industry. The 2015 energy policy updated that from 2002. Thermal and hydroelectric power were emphasized in 2002, while private investment and large-scale power projects were promoted in 2015. Similarities exist between current and historical power restrictions. Foreign investment

restrictions were eased, notably for energy professionals. Low-cost production permitted 50-MW energy plants. The 2015 GOP energy policy did not prioritize renewable energy.

2.3. Development and Expansion of Renewable Energy Policy 2006 and 2019

In the creation of a renewable energy policy framework in Pakistan, solar and wind energy resource evaluations were first, followed by biogas, biomass, and waste-to-energy. Foreign investment was emphasized in the GOP's 2006 green energy agenda [26]. The 2006 policy ended in March 2018, prompting new renewable energy efforts. In ARE 2019, new standards for renewable energy development were created. ARE policy sought to minimize grid power production costs, encourage green energy consumption, assure transparent bidding procedures, and support the creation of ARE-related local companies as shown in Figure 6. The ARE 2019 strategy was similar to the 2006, but it emphasizes green energy more. The new policy applied carbon development, and it aimed to reduce greenhouse gas emissions using the Kyoto Protocol. There were 18 projects registered to reduce greenhouse gas emissions by 1.3 million, kiloton and 29 renewable energy projects were registered to reduce emissions by 1.5 million kiloton. In general, the GOP increased Pakistan's use of renewable energy. Since AEDB's founding in 2002, renewable energy has had little impact.

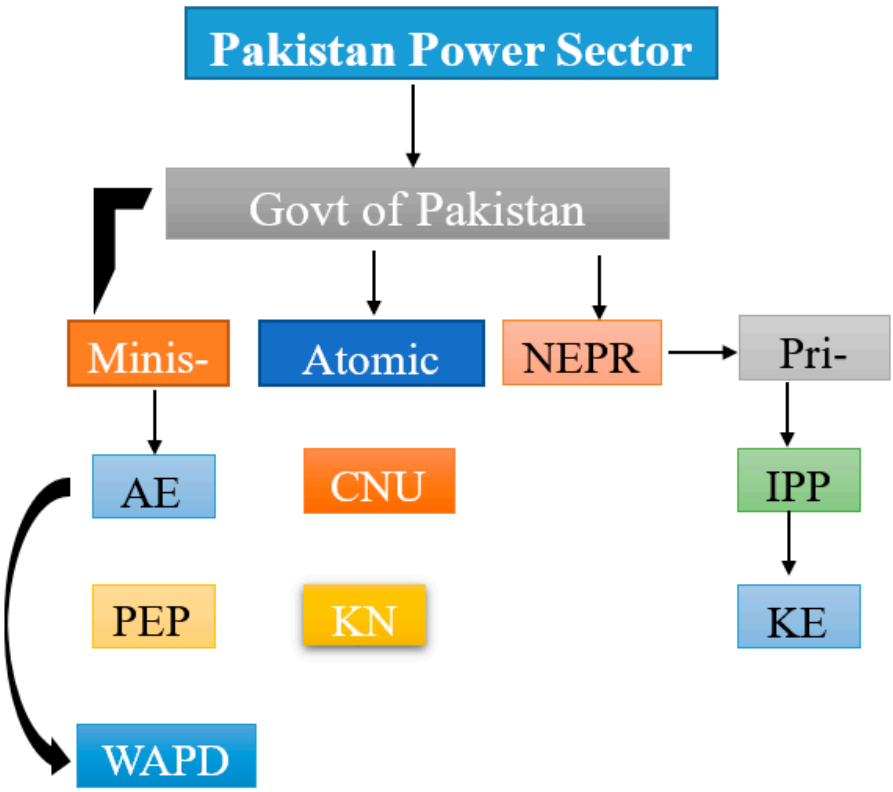

Figure 6. Power sector structuring in Pakistan.

3. A Guiding Framework

The GOP proposed a well-thought-out plan for implementing and regulating energy projects. The most encouraging development was the creation of the National Electronic Power Regulatory Authority (NEPRA), an institution in charge of monitoring and administration. NEPRA was founded to monitor all elements of energy regulation, such as the issuance of licenses, the definition of standards and prices, the generation of performance reports, the establishment of standardized procedures for DISCOs, and the promotion of renewable energy throughout the country.

3.1. Renewable Energy Environment in Pakistan

Pakistan has access to a wide variety of different energy sources. It is possible to create energy using the earth's natural resources [2,25]. Due to its varied topography, consisting of plains, deserts, mountains, and glaciers, Pakistan is an excellent site for a wide variety of possible commercial endeavors. In the northern area, success can be seen across the board for projects of all sizes [27]. Due to the high levels of sunshine in the region's geographic center, this is an excellent site for constructing wind and solar power facilities. Both Sindh and Baluchistan have been recognized as having a substantial amount of untapped potential for wind resources. Pakistan is a country that heavily relies on agriculture and can produce power as a result of its sugar cane industry.

3.2. Hydropower Energy

Water energy (hydropower) is one of the useful, cheap ways to obtain energy, and Pakistan has taken the advantage of this cost effective source of energy. Pakistan has undertaken several hydroelectric projects. Since June 2015, hydropower has reached 7120 megawatts. Hydro-dams provide energy and store water for crops during droughts, which is important to many people live in villages and work in agriculture.

WAPDA held 6902 megawatts, whereas international power producers (IPPs) owned 213 megawatts. Private investment is crucial for large hydropower projects, such as Suki Kinari Hydropower, Azad Pattan Hydropower, and Chakothi Hattian Hydropower. China is also interested in Pakistan's water development.

Figure 7 presents China's Karot hydropower project. Build, own, operate, and transfer (BOOT) was used for the first time in the Silk Road's 30-year history. NEPRA's tariffs for the projects show their development. These initiatives utilize a minuscule proportion of the 65 GW of available technology. Pakistan's KPK and Gilgit-Baltistan have 45 GW of hydropower potential. Hydro developments in Gilgit-major Baltistan are still being built. The lack of connectivity to the national distribution network and remoteness have impeded GB's hydropower projects. The river system's geography likely enables hydropower production in KP and Punjab. The KPK Energy Development Board is developing small dams able to produce 272 megawatts. The private sector has been given policy guidance to help construct 28 hydroelectric projects with a 122-megawatt capacity. Since 2008, PPDB has focused on small-scale energy initiatives.

Figure 7. Karot hydropower project in Pakistan under CPEC.

3.3. Solar Energy

According to [28], global irradiance has an effect on solar photovoltaic installation. The south and southwest are the regions with the greatest radiation levels [29,30]. The sun irradiation is highest in the southwest region of Pakistan, while it is lowest in the north and northeastern parts of the country. The annual global horizontal irradiance in the Himalayas and Karakorum is 2300 kWh/m^2, which is the greatest of any other region on Earth. The numbers that have been measured decrease as one travels northeast. This location receives a

healthy amount of sun [31]. Figure 8 depicts the sun irradiance mapping for Pakistan by the World Bank. DNI is a solar PV cell standard. Solar PV is highest on dry ground [32]. Except for the Himalayas, DNI is widespread throughout Pakistan [33]. Western Baluchistan has 2700 kWh/m^2/year, and 80% of the land can produce 2000 kWh/m^2/year. Comparing our assessed values to sub-Saharan values yields good results (Sinai Peninsula). PV-Sol Software was used to determine DNI values for four provinces. Karachi and Hyderabad have a DNI of 1834.5 kWh/m^2/year in Sindh. Sukkur and Jacobabad's DNIs were 1931.5 and 1934.7 kWh/m^2/year. Multan, Bahawalpur, Faisalabad, Sialkot, and Lahore have DNIs of 1998.3, 1941.3, 1639.9, 1671.1, and 1640 kWh/m^2/year, respectively. Quetta, Zhob, and Qila-Saifullah's DNIs were 2039.6, 2040.9, and 2014.8 kWh/m^2/year. AEDB has authorized and is developing solar power installations in some of these sites. The AEDB has 22 solar PV projects totaling 890.80 megawatts. Six solar power facilities totaling 430 megawatts have been in operation for five years.

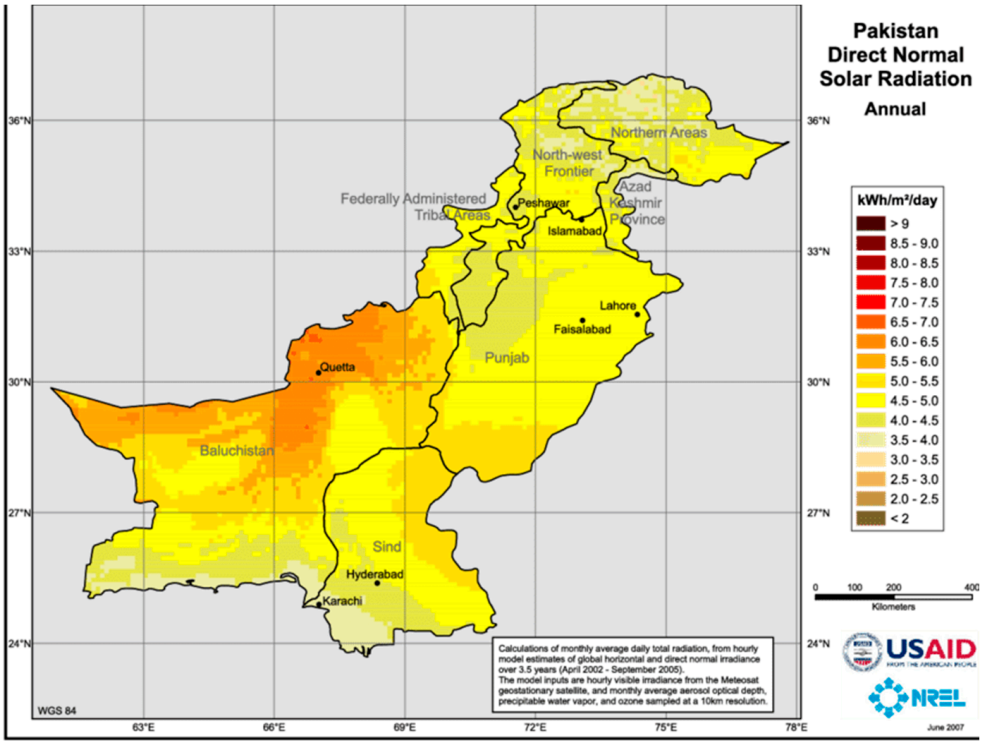

Figure 8. Solar irradiance of Pakistan.

3.4. Wind Energy

Wind energy is a primary renewable source, and the process of wind mapping involves international and local organizations. The Pakistan Meteorological Department (PMD) and National Renewable Energy Laboratories map wind. Figure 9 shows Pakistan's wind energy potential at 50 m above sea level (ASL). This information comes from satellites and on-the-ground sensors. The World Bank's wind research in Pakistan as part of ESMAP helped identify the most critical sites. Wind energy researchers are also featured [20,21,34,35]. Pakistan's wind energy potential is 300 GW.

The Republican Party emphasized southern Pakistan's 50 GW Gharo Ketti Bandar wind corridors. The following publications contain information on the wind resource and economic assessment [36,37]. Gharo's wind resource and energy economics were measured at 10, 30, and 50 m. The authors found the site suitable for utility wind turbines [38]. Karachi Port Trust's (KPT) wind resource analysis reveals that the site can produce power [36]. Sujawal's wind resource and energy potential were assessed at 20, 40, 60, and 80 m [36]. At 20, 40, and 60 m, Sanghar's wind resources and energy potential were analyzed. The site showcased cheap energy generation [38]. Another probable Quaid Abad site study was performed 20, 40,

60, and 80 m from Karachi, Pakistan's most prominent industrial center. The feasibility study shows that utility wind turbines can produce power [37]. The literature covers many types of research evaluating Pakistan's wind resources at different elevations.

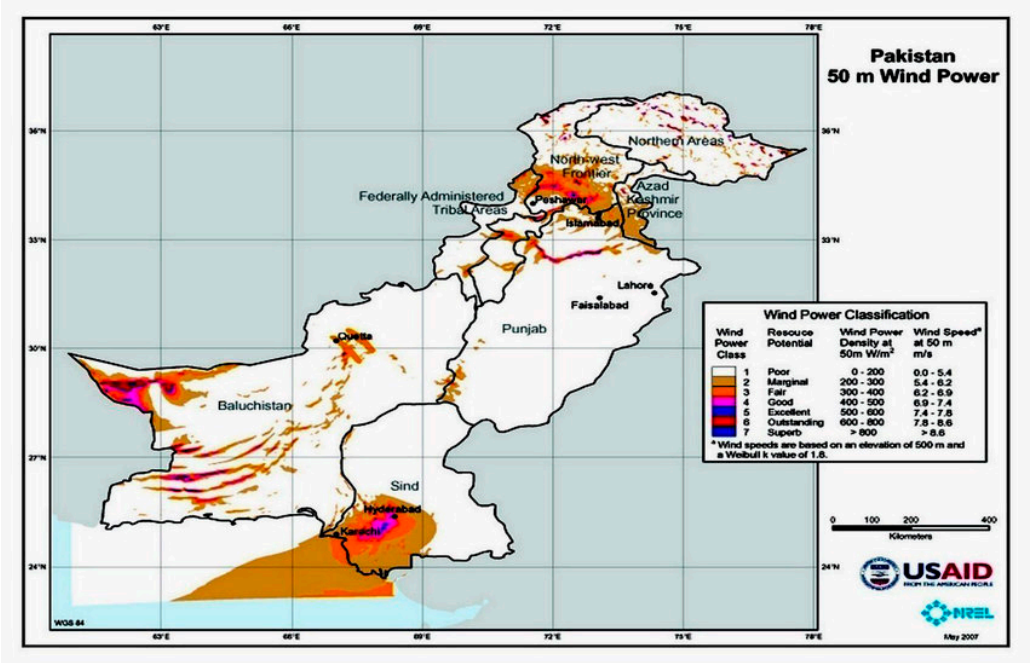

Figure 9. Wind energy assessment of Pakistan.

Gharo-Ketti Bandar can generate 1000 megawatts. The AEDB says wind energy initiatives are succeeding. The government wanted to generate as much wind energy as possible to lessen the dependence on more expensive sources. Sindh has issued 23 LOIs for wind energy projects in this region. Punjab's administration has shown a readiness to employ wind energy with the installations capacity to generate 1710 megawatts.

3.5. Bioenergy

It is essential to consider the use of bioenergy as a resource [39]. The bioenergy mapping in Pakistan was completed in 2016. The biomass map that has been developed has two components: Utilizing satellite imagery in conjunction with field surveys to categorize the land might, in theory, be used to evaluate the biomass energy potential of an area. The second part of this process is an analysis of the technical potential based on the survey results, which may identify patterns of yield utilization [40]. The most important sources of biomass in the United States are found in the industrial and agriculture sectors. In addition to rice and maize husks, the husks of various other crops are also used as biomass sources in industrial settings.

On the other hand, rice straw and wheat straw are two good examples of agricultural biomass sources. By the end of December 2016, four sugar mills had completed the construction of bagasse energy-producing facilities. Forty-five megawatts of total installed capacity may be found in a single bagasse plant. Bagasse power stations that are presently being developed now have a capacity of 217 megawatts. As can be seen in Figure 10, a letter of intent to produce biomass energy has also been handed to a number of other companies during the course of the last five years.

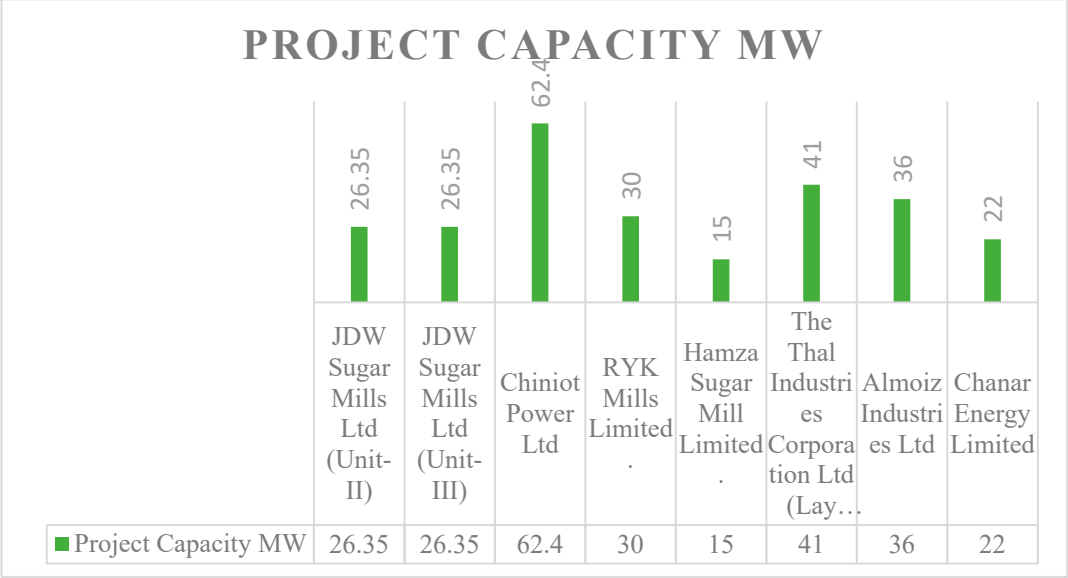

Figure 10. Under the ECC-approved policy, a letter of intent to produce biomass energy was handed to the following companies.

3.6. Geothermal Energy

The vast majority of Pakistan's geothermal energy potential has not yet been exploited [41]. There is not yet a methodical approach that can be used to evaluate the possibilities of geothermal energy exploration. On the other hand, a number of studies have shown that geothermal energy can be produced over the whole of Pakistan's provinces [42]. Despite that offshore mud volcanoes are very uncommon in the Makran region's shallow shelf area, the mud active zone (MAZ) is the collective name given to the mud volcanoes found in the region. The satellite images of mud volcanoes reveal a distinct flow and flux, both of which can be clearly seen. According to the geological survey of Pakistan, the principal hotspots for geothermal activity may be found in the Himalayan collision zone, the Indus basin, and the Chaghi area of Baluchistan. Researchers discovered indications of geothermal energy in areas that were also prone to seismic activity. In light of this, the conclusions of the quantification are applied to the task of estimating the probability of geothermal resource exploitation. Despite this, geothermal energy needs to be assessed, and the ideal areas need to be determined. As a consequence, the evaluators are required to conduct further evaluations and incorporate their results. Alternative energy sources such as geothermal energy are often considered to be feasible options.

3.7. Systematics Policies and Initiatives for Developing Renewable Energy

The Republican Party established the American Energy Development Board (AEDB) to further the cause of renewable energy. The board of directors came up with a policy on renewable energy by using a three-pronged strategy [43]. The AEDB created its first program about renewable energy in the year 2006. However, before 1994, the announced energy policy allowed the private sector to participate in building renewable energy facilities such as wind, solar, and biomass, as well as the subsequent development of conventional energy plants. As a consequence of developments in technology, the cost of maintaining renewable energy-producing facilities has become less expensive. Due to the efforts made by the GOP to attract foreign and private investors, such investors may invest in renewable energy. The policy resulted in significant profits being accrued to investors.

The AEDB made it simpler for private parties to carry out initiatives, including renewable energy. According to the proposers, this method is utilized to construct renewable energy projects that are not desired by anybody else. The AEDB is now assessing the request, and once they are finished, they will issue a letter of intent (LOI) to finance the

technical paper [27]. In the future, permission from the AEDB and NEPRA will be necessary for the commencement of generating and tariff operations. The three most important documents that the regulator has issued are the energy purchase agreement, the implementation agreement, and the land lease.

4. Renewable Energy Infrastructure Development

It is standard practice for renewable energy projects to be built in remote areas of the country that are significantly far from traditional grid centers. For instance, the recently built Ketti Bandar-Gharo corridor is a considerable distance from the distribution network that is now in place. The National Transportation and Development Corporation (NTDC) is faced with a significant obstacle in the form of power transmission [40]. For instance, in a remote Punjab region, a solar park was just built and given the name Quaid-e-Azam. Consequently, an increased amount of capital will be required to construct a distribution network even though the prices of variable renewable technologies and code integration have dropped significantly over the last ten years.

4.1. The Renewable Policy Developed by the State Bank of Pakistan

In 2009, the State Bank of Pakistan developed a program that provides financial assistance to promote Pakistan's policy toward renewable energy. The modifications made to the renewable energy program in June 2016 affected not just investment institutions but also financial institutions. The initial policy's financial constraints were between 5 kW and 10 megawatts of installed capacity. However, in the revised version of the renewable energy policy in 2016, the capacity was increased to 50 megawatts.

4.2. Guidelines for Competitive Auction and Bidding

The government has sent fundamental guidelines for the bidding process for energy production and transmission networks. In this regard, a tariff guideline for 2017 was produced as a benchmark to serve as a reference point. As a direct consequence of this, the bidding process was underway. The federal government has the whole burden of responsibility for dictating policies to the regional governments. The Republican Party will make the decisions that matter most. On the other hand, provincial administrations are actively working to promote the installation of renewable energy sources.

4.3. The Renewable Energy Tariff Agreements

The tariff agreement is necessary to ensure the economically viable operation of the power plants. The cost-plus-tariff setting method is included in the recommendations for renewable energy that were outlined in 2006, and this contributes to the document's increased accessibility. The tariff NEPRA has in place for wind energy projects is an excellent illustration of a cost-cumulative tariff. The levelized energy cost for wind-generating facilities in Pakistan is between 11.35 and 13.70 Pakistani rupees per kilowatt-hour. NEPRA devised a plan to alter methods concerning the technology-based upfront pricing. There are variations in the method by which upfront tariffs are computed and the period for which they are valid. These variations depend on the provenance of the underlying technology.

4.4. The Energy Policies for Rural Electrification

At least 65% of the country's population resides in rural areas, with most of the remaining population working in agricultural occupations. The federal regulation does not give any effective policy mechanisms for the electrification of rural areas. Therefore, it is of the utmost importance that initiatives for the electrification of rural areas be formulated with the assistance of the commercial sector and put into action. The electrification endeavor needs to include more private investment in a significant capacity. The GOP can make sensible judgments as long as they have Pakistan's energy future in mind. Renewable sources of energy, which are plentiful, have the potential to play a significant part in mitigating the adverse effects of rural electrification. Rural communities in several developing countries,

such as Bangladesh, Kenya, India, and Sri Lanka, have been electrified by using a wide range of approaches and procedures.

4.5. Challenges and Recommendations for the Energy Sector

Pakistan needs a detailed strategy for its energy demands. It is helpful in the cost–benefit analysis of the supply–demand cycle because it considers the limits imposed by technological, economic, and environmental factors. Due to the constitutional arrangements between the federal and provincial governments, there has been an increased focus placed on the need for an integrated energy policy. Following an amendment to the Constitution in the 18th century, each province was granted the authority to establish its very own departments of energy. Representatives from the public and commercial sectors must be included in the decision-making process on planned investments in electricity generation, transmission, and distribution. In Pakistan, the government operates according to a parliamentary framework. If different parties control the federal and provincial governments, there is a greater chance that severe gridlock may occur over matters of national significance.

Consequently, this leads to delays that last for an extended period, impediments that prevent the projects from being finished, and a lack of interest from foreign investors in energy projects. Similar to matters about the federal and provincial governments, the Constitution grants a dual nature. By passing legislation on these matters, the federal and provincial governments will be more estranged, which might result in conflict. Following the adoption of the 18th constitutional amendment, the responsibility for the energy department was split between the central government and the provinces.

It is generally agreed that the integrated energy strategy should serve as the foundation for the power sector's efforts to make the most of its available energy resources. To meet demand as efficiently and economically as possible, the least expensive energy planning produces a competitive energy fusion of sources. This is performed to fulfill demand. An integrated energy planning approach is strongly advocated as a means of assisting in the construction of energy-related infrastructure. This is a significant challenge that the energy sector in Pakistan needs to overcome. Consequently, we are presented with a once-in-a-lifetime chance to develop a comprehensive, interdepartmental, and interprovincial plan for renewable energy development.

4.6. Realization of Achieving Goals from Renewable Energy

A non-conventional energy plan is necessary if one wants to take advantage of Pakistan's substantial non-conventional energy resources. Alternatives to the current energy strategy that are well-structured, accurate, and updated in real-time might help achieve this objective. The capacity to envision renewable energies as the sector's future would benefit the renewable energy industry. A significant number of the goals have not been accomplished because they are not legally enforceable, and the government has not yet devised a strategy for putting them into action. On the other hand, the nation's financial constraints have severely constrained the government's capacity to take independent action.

It is possible to achieve the level of non-conventional energy deployment required with the aid of integrated energy planning. With the assistance of a well-coordinated energy plan, it should be possible to achieve the goals. However, to comply with the federal law requirements, the goals must be explicated in detail inside the policy instruments. This comprises many agreements, such as tariffs and energy purchase contracts.

4.7. Renewable Energy Relationship with the High Cost and Advanced Technology

Concerns have been raised about the effectiveness and cost per kilowatt-hour of renewable energy sources when contrasted with those of more conventional energy sources. It was formerly believed that the rising prices of the materials required to create renewable energy were incompatible with the concept of renewable energy. Due to advances in technology, energy efficiency has increased, leading to a decrease in the price of a kilowatt-hour and an increase in the amount of competition in the market. Utilizing renewable

energy (RE) sources is associated with a declining trend in the costs of business in Pakistan. It is possible to observe this in Pakistan's prices for renewable energy. The producer and the regulator agreed on the tariffs for wind farms, which set them at USD 0.147 per kilowatt-hour. As of the time this article was written, the standard tariff was USD 0.67 cents per kilowatt-hour.

Nevertheless, the economics of generating energy from fossil fuels are not completely solid. This is the case even though Republicans are more likely to support energy models that rely on fossil fuels than renewables. There is a possibility that including renewable energy into energy blends and customer basket pricing will have substantial short- and long-term implications. Additionally, it is the NTDC's responsibility to ensure that the network is accessible for using renewable energy sources.

4.8. Encouraging the Private Sector to Develop Infrastructure by Providing Incentives

It is a common practice to grossly underestimate the importance of private investors in building the infrastructure. Nevertheless, the legislation regarding renewable energy emphasized the private sector's participation in expanding the grid and transmission networking. Having implemented a new plan for the use of renewable energy sources in 2015, the NTDC currently has exclusive authority over the construction of grid and distribution network projects. NEPRA was responsible for designing the first transmission line project that included the concept of a transmission tariff. This was the very first private sector transmission project in Pakistan, and it was developed under the "build, own, operate, transfer" (BOOT) business model. By using this method, the private sector has set a precedent for its involvement in establishing a grid and linking transmission lines. This was accomplished via the use of this technique. It will minimize the government's obligation to use government capital and make it easier to develop the network, provide help and alter laws, and construct additional grids and stations.

4.9. Getting the Micro-Grid off the Ground by Starting a Grass-Roots Movement

The rural areas of Pakistan are home to more than 65% of the country's population, and the agriculture industry employs the vast majority. It is essential to have integrated energy planning to eliminate the technical, financial, and energy policy obstacles that stand in the way of electrifying the rural areas of Pakistan. A concerted effort is necessary for the development of grids and the greater engagement of huge communities. Consequently, this necessitates establishing an extremely stringent framework for energy rules and regulations, the primary objective of which is to promote the concept of tiny grids and hybrid systems that operate independently [34]. People who live in remote areas and are cutoff from access to the national distribution network may benefit significantly from the concept of tiny grids. Small grids are becoming more popular because they provide greater operational flexibility and cheaper energy prices when compared to conventional power plants that run on fossil fuels [5]. In Pakistan, encouraging the development of micro-grids may also include luring local and international investors in the country's energy sector. The provision of legal and license provisions, tariffs and costs, financial facilitation, technological considerations, service considerations, and other issues can be addressed more effectively with regulatory flexibility provided by the government. This may be of assistance to private sector investors. Although these policies need some tweaking to entice both domestic and international investors, Pakistan is making progress toward its goal of developing renewable energy by encouraging the creation of smaller networks. It is not easy to choose just one example, but plenty are available from other nations, such as Tanzania, Kenya, and Nepal. In these countries, a framework of rules and procedures, incentives, and hazards, tailored explicitly to tiny grids, has been constructed. These experiences help us to create policy manuals that take into consideration a range of critical issues, including the construction, the size, the energy resources, their availability, the finances, the tariffs, and the affordability of the options.

5. Discussion

Numerous national and international organisations assess renewable energy sources. The examination of renewable resources in Pakistan revealed great availability. According to resource assessments, Pakistan's energy policymakers recognise the necessity and benefits of developing renewable energy. The expansion of renewable energy has the potential to bring about a variety of benefits, such as improved energy security, decreased reliance on a single source of supply, increased diversity of sources, less impact on the balance of payments and the circular debt, greater social cohesion through deployment in remote regions, new employment opportunities, a more vital engineering industry, and an enhanced perception of the country as environmentally friendly. The significance of the aforementioned regions was well-depicted on geographical maps. Maps and computations demonstrate the renewable energy potential of specific regions. Planning could facilitate the growth of renewable energy sources and community empowerment. The AEDB provided an urgent and long-term policy on renewable energy. The three-pronged strategy of the AEDB has hindered it from achieving its declared objectives. This investigation determined that energy efforts have a long way to go. Another danger is AEDB's lengthy procedure for evaluating energy purchase agreements with the GOP. Multiple energy projects are in the planning stages, but tariffs have not been established. People may mistrust the motivations of the government. Therefore, private investors are wary of Pakistan. We drew this conclusion after examining numerous renewable energy companies, including those in Pakistan. The previous Pakistani energy policy was centred on private investors, despite the fact that every issue affects businesses. Other essential factors include integrated energy planning, achieving the AEDB's goals, establishing a clear boundary between the most suitable site and transmission network limits, and on-grid and off-grid limits.

Conclusions

This research paper evaluated Pakistan's energy policies and the availability of renewable energy sources. The prospective analysis revealed a vast availability of renewable energy sources, such as hydro, wind, solar, bioenergy, and geothermal power. The rapid expansion of renewable energy in Pakistan, however, has been hampered by a lack of financial resources and a conventional mindset. Renewable energy can improve energy security, increase supply diversity, decrease cyclical debt, and stimulate the nation's engineering industry. This article highlights the significance of the energy mix and may prompt policymakers to reconsider their approach. The evaluation of potential energy showed system inadequacies. It emphasized the importance of private investment in all programs for renewable energy. There are various obstacles to installing renewable energy systems in Pakistan. This research paper provided essential recommendations that, if implemented, would result in energy generation at the most affordable cost and a decrease in load shedding in Pakistan. The recommendations in this paper will determine Pakistan's transition to renewable energy. These recommendations include federal and provincial energy planning, the achievement of renewable energy goals, the adoption of more advanced technologies, the prioritization of high-potential sites, the development of grid and transmission infrastructure, and the expansion of private investment. Pakistan's transition to renewable energy necessitates all these elements.

6. Limitations of the Study

The federal government has committed to a new path toward renewable energy and is establishing the Renewable Energy Authority AEDB. The AEDB, NREL, and PMD researched the available wind and solar resources. The most significant stops were made at Bahawalpur, located in the southern part of Punjab, and Gharo-Ketti Bandar, in Sindh. The areas that needed infrastructure development were those that were situated at a sufficient distance from existing facilities to necessitate a strategy that was both comprehensive and proactive. As a direct consequence, the GOP is having a hard time addressing the monumental challenge posed by widespread energy shortages.

On the other hand, a deficiency in development funds may prohibit large-scale expenditures, which are essential for satisfying the requirements of the infrastructure. The transmission and network structure in Pakistan is insufficient owing to several factors, including the absence of financial aid, the absence of interest from the private sector, and political instability. Despite this, the country's plan for energy has not been successful since insufficient money has been designated to build new energy infrastructure.

7. Implications of the Study

7.1. Managerial Implication

When it comes to attaining the goals they were intended to achieve, energy policies have repeatedly proved that they are ineffectual. Taking energy shortages as an example, Republicans have made progress in reducing their impact, but the root cause remains. Weirdly, Pakistan seems to lack any formalized energy planning. New policies were implemented, or energy policies were changed without thoroughly examining the possible benefits and drawbacks of the endeavor by the new political party in Pakistan. Several renewable energy programs, most notably hydropower projects, have sparked societal anxiety because of their perceived negative social impacts. Much of Pakistani society and political organizations were opposed to the hydroelectric projects. A significant point of contention was the controversial Kalabagh Dam project, which caused a gap between the provinces and the federal government. Regardless of what the provinces decide, the building of the Kalabagh dam will continue. However, unlike hydroelectric projects, solar and wind power development have not faced the same public resistance. Indeed, since solar energy is a cost-effective source of electricity, the region's citizens voted in favor of the projects. People have become more comfortable with solar power as the market for solar panels has grown.

7.2. Policy Implication

To boost the number of solar power plants, the current government political party is also pushing for a policy that favors investors. Another example is Roshan, a series of solar energy initiatives sponsored by Punjab's state government. The government of Pakistan considers it a top priority to install solar panels on government buildings, including schools, offices, and primary healthcare institutions. Solving public policy problems focuses on identifying and addressing the difficulties brought to light. Another problem is that Pakistan's electricity industry is fragmented, with dozens of different organizations involved. The AEDB is currently completing the projects, while the NEPRA is working on defining their tariffs. For the spread of ARE, several institutional structures need to be consolidated. To enhance harmonization, the AEDB, NEPRA, State Bank of Pakistan, SME organizations, and NGOs are some of the primary players. The federal and provincial governments, the federal and provincial energy departments, and the AEDB and NEPRA are the other parties involved.

Author Contributions: Conceptualization, Y.X., W.A.W., M.K.B.D. and H.A.; methodology, Y.X., W.A.W., M.K.B.D. and H.A.; formal analysis, Y.X., W.A.W., M.K.B.D. and H.A.; investigation, Y.X., W.A.W., M.K.B.D. and H.A.; writing—original draft preparation, Y.X., W.A.W., M.K.B.D. and H.A.; writing—review and editing, W.A.W. and M.K.B.D. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Humanities and Social Sciences Research Fund Project of the Ministry of Education (17YJC880145), Jiangsu Province, "333 High-level Talents Training Project", and the Young and Middle-aged Academic Leader Project (2018SZJS-005). This research is also supported by the National college students' innovation and entrepreneurship training program (Project No. 20210616015).

Data Availability Statement: The supporting data will be provided upon responsible request.

Conflicts of Interest: The authors declare no conflict of interest.

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