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Evaluation of Drivers and Barriers of Wind Power Generation in Pakistan: SWOT-Delphi Method

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ABSTRACT

In the last two decades electricity shortage has hampered the economic growth of Pakistan. To overcome these crises, thermal power plants were commissioned to bridge the supply and demand gap. Deployment of thermal power generation resulted in an unsustainable energy mix with the higher cost of generation. In the last decade, policymakers have shown considerable interest in deploying renewable energy generally and wind energy particularly. Therefore, this paper evaluates some important drivers and barriers to wind power generation. SWOT-Delphi approach with Relative Importance Index (RII) analysis has been applied. The results show that the deployment of wind power can enhance energy security and environmental sustainability. Major barriers to wind energy are the presence of competitive energy resources, policy implications, and poor grid infrastructure. With this contrasting environment, the evaluation of drivers and barriers of wind power are insightful for formulating sustainable energy planning strategies for future generation mix.

Keywords: Wind Power Generation, SWOT-Delphi Method, RII Analysis
JEL Classifications: P4, Q4

1. INTRODUCTION

Globally, renewable energy has a huge potential and can meet the world's power requirements. The world can enhance electricity generation from renewables with a high degree of reliability, affordability, and sustainability. It also offers commercially smart opportunities to provide energy services, largely for rural areas and developing regions. Additionally, it will create employment opportunities for the local community and indigenous trade for the industrial side from a manufacturing point of view. By the end of 2015, the total cumulative global installed capacity of wind power reached 432,419 MW which is about 25 times the installed capacity in 2000. It is anticipated that by 2030 installed capacity will reach 2000 GW supplying about 16.7-18.8% of total electricity produced (Ren et al., 2017). Many developing countries are also following the footprints of the developed world to undergo the transition from conventional power generation methods to renewables. Pakistan is also blessed with an abundant potential for renewable energy especially wind power. The determined wind potential of the coastal belt of Pakistan is 43 GW. According to the National Renewable Energy Laboratory (NREL), Pakistan has 346 GW of wind energy potential for electricity production. The wind energy potential in the country is abundantly available in the coastal belt of the Sindh and Baluchistan provinces of Pakistan with an average wind speed of 7 m/s at 50 m anemometer height (Shakeel et al., 2016). The potential sites along the 9700 km^2 coastal areas in the Sindh province of Pakistan are Jamshoro, Jhampir, Mirpur Sakro, Keti-Bandar, Thatta, Shah Bandar, Gharo, and Nooriabad. However, in the province of Baluchistan, Hub, Gawadar, Ormara, Gadani, and Jiwani, are the best sites of wind potential. Currently, Pakistan has a wind generation capacity of around 1200 MW and many wind projects are under various stages of completion. As per Alternative and Renewable Energy Policy 2019, the country has set a target of 30% share of renewable in the total energy mix by 2030. In the future, renewable energy and particularly wind power appears to play a significant role in the energy sector of Pakistan. Therefore, it is imperative to evaluate the drivers and barriers of wind power. SWOT in this regard is a very useful tool to evaluate the strengths and weaknesses of generation methods such as wind. SWOT is a strategic planning tool. It is a methodology allowing the industry to understand and plan to use their strength to exploit opportunities to diagnose and mend or avoid their weaknesses and to protect against any unknown threat. SWOT analysis permits better-structured qualitative analyses of predefined issues, second, SWOT is a strategic analysis tool aimed to improve the system. It is, therefore, more vibrant and thus better able to recognize potential modifications that improve policy strategy. The consistency of a policy can be verified by SWOT that involves several parallel objectives. At the same time, SWOT analyses have several limitations. SWOT analysis is often subjective even if the analysis is well structured and an agreement about its results may be difficult to achieve. Furthermore, even if it permits us to recognize the strategic axis of a policy with many objectives and complex expected impacts, it simplifies the real problem. Finally, it can be difficult to differentiate between internal and external factors, leading to ambiguity between strengths and opportunities or between weaknesses and threats. It is therefore important to define external and internal factors before the SWOT analysis is done.

Bringing about a clearer common purpose and understanding of factors for successful generation methods, many generation sources have been evaluated with SWOT. (Zhao and Yan 2012) reviewed and assessed the factors of strengths, weaknesses, opportunities, and threats of biomass power generation of China. They used statistical reports literature review regulation policies and case studies. With SWOT analysis, they provided valuable information to devise future development and potential risks associated with biomass power. (Lei et al., 2019) used an approach of SWOT analysis by investigating internal strengths, weaknesses, opportunities, and threats for the photovoltaic solar development of Africa. The authors identified that Africa has a great potential to exploit solar energy with the cooperation of China and international cooperation within the framework of the Belt and Road initiative (BRI). (Shi, 2016) assessed the challenging outlooks for energy mix in the Association of Southeast Asian Nations (ASEAN) stressing the impact of fossil fuel-dominated outlook when compared with its ambition to move toward green energy policies using strengths, weaknesses, opportunities, and threats. The author argues that despite the brown look due to the growing surge of coal, the ASIAN region has many advantages in offering cleaner and greener energy for its green vision. For this target to achieve, the countries need to make further efforts to promote renewable energy, energy efficiency, regional market integration, and connectivity. Author links open overlay panel. Ervural et al. (2018) conducted SWOT analysis for Turkey's energy sector and anticipated an integrated hybrid methodology using strengths, weaknesses, opportunities, and threats (SWOT) analysis, Analytic Network Process (ANP), and weighted fuzzy techniques for order performance by similarity and holistically examined the energy strategy substitutes and priorities. The technique recommended in this study allowed identifying relevant criteria and sub-criteria using SWOT analysis. (Khalil, 2017) conducted a SWOT analysis of nuclear power electricity generation. He concluded that nuclear power generation along with other renewable energies is a viable option to reduce greenhouse gases. He further concluded that fossil-fueled power plants should be integrated with Carbon Capture and Storage (CCS) technology. (Fertel et al., 2013) discussed Canada's federal and provincial government's coherence while implementing the climate and energy policies. They tried to identify the prospects and challenges of energy policy in implementation with SWOT analysis. (Ishola et al., 2019) identified the positive and negative aspects of deploying nuclear energy in Nigeria with a SWOT matrix. The authors reviewed Nigeria's venture into nuclear energy while considering global efforts towards nuclear security and safety. They concluded that nuclear energy can be harnessed in Nigeria while maintaining global safety practices.

In Pakistan, SWOT studies on the power generation sector are few which are mainly focused on qualitative analysis of renewable energy. Wang et al. (2020) conducted SWOT analysis of renewable energy of provinces of Sindh and Baluchistan of Pakistan. The fuzzy Analytical Hierarchy Process (Fuzzy AHP) has also been used. Three renewable resources (wind, solar, and biomass) have been assessed as alternatives in the decision model. They found that economic and sociopolitical are the two most important criteria. They concluded that wind has ample potential to generate electricity in both provinces. Kamran et al. (2020) performed a SWOT analysis of renewable energy in Pakistan. Authors pinpointed that huge resource potential and renewable energy maps are the strengths, while poor institutional infrastructure is its weakness. The untapped potential, micro, and mini installation are few opportunities. The threats to renewable energy are the presence of competitive energy resources, policy implications, and grid connection.

Finally, they concluded that the retainability of renewable energy is necessary for energy security and sustainability for Pakistan's power sector, such as significant advancement to attain energy security and sustainability. (Shakeel et al., 2016) reviewed the issues of the power generation sector in general, the role of renewable energy in the overall mix, and very precisely touched the sustainable pathway with SWOT analysis. They summarized that Pakistan has sizable reserves of coal and the opportunity to develop gas infrastructure, inefficient utilization of domestic resources, high transmission and distribution losses have been regarded as a weakness in the system. Authors have pinpointed the opportunities of distributed generation and smart grid. They concluded that to protect from threats, Pakistan must reduce reliance on excessive imported fuel and reduce the cost of unit generation of power. From the extensive review of literature, it is found that most of the studies have qualitatively analyzed the strengths and weaknesses of power generation methods. This study thus has focused on quantitative analysis with Delphi and RII tools to find the most prominent factors responsible for the development of wind power and deficiencies hindering the deployment of wind power. Evaluation of drivers and barriers of wind power development will help decision-makers share and compare results in bringing about a clearer common purpose and understanding of factors for successful wind power deployment. The organization of this paper is such that methodology is given in section 2. The results and discussion are explained in section 3. Conclusion and policy recommendations are presented in section 4.

2. METHODOLOGY

SWOT Delphi hybrid model was used to evaluate the drivers and barriers of wind power in Pakistan. SWOT analysis in this regard is a very useful tool to find its strengths and weaknesses alongside opportunities and potential threats. RII analysis was conducted to find the most prominent positive and negative attributes of wind power generation.

The SWOT analysis of Pakistan's wind power generation was accompanied by answering the following questions with the help of a detailed review of literature, announced energy policies, reports of Pakistan's power regulatory agencies, national and international articles, newspapers, books, electronic materials, and Delphi statements received from experts in response to questionnaires sent to them.

- What is the level of experience of human resources?
- What is the level of the physical and institutional infrastructure of wind power generation?
- What is the wind potential in Pakistan?
- How reliable is the wind power source?
- What is the level of government's willingness to invest in wind power projects?
- How environmentally friendly are wind power plants?

Answering these questions with the help of two-round questionnaires enabled this study to assess the drivers and barriers of wind power in Pakistan. Closed-ended and open-ended questionnaires were sent through email to experts of wind energy from various sectors. The theme of SWOT was energy security, economic viability, and environmental sustainability.

2.1. Delphi- SWOT Paradigm

The SWOT analysis of Pakistan's wind power generation was accompanied by the Delphi approach. Delphi's approach is well suited for consent building. Delphi's approach helps in reaching a consensus on critical issues in a diverse environment. It is a process to decide on any ambiguous topic based on a survey of respondents' judgment. The following procedure was adopted in the Delphi method during the study.

- Experts from the wind power generation source were first identified and requested to take part in the survey. Experts were middle and senior managerial persons who had an adequate understanding of the field of wind power.
- The Delphi statements were developed by the authors and pursued through various successive questionnaires.
- Experts were requested to give their opinion on the strengths, weaknesses, opportunities, and threats of wind power generation.
- The range of participants' opinions has been identified by the Likert Scale.
- The extreme opinions were re-evaluated by the participants in the second round.

Lastly, a SWOT strategy was formulated before the proper evaluation of wind power generation. Questionnaires were delivered in two rounds using multiple iterations to collect data from a panel of the selected field. The expert's assessment was weighted by the Likert Scale. In this study, the Likert scale was judged from 1 to 5 points. Each point's comment was recorded. The expert's opinion in the field of strengths, weaknesses, opportunities, and threats was calculated in descending order based on the expert's weighted evaluation (Table 1).

Mostly, respondents were from academia followed by government organizations and research institutions as shown in Figure 1.The feedback regarding the weightage of anticipated issues was collected by sending questionnaires online in two rounds. The names of experts were kept confidential as per the understanding before sending the questionnaire to them. The number of experts for various power generation technologies was varying depending on the accessibility of experts. They were contacted to reply to the questionnaire in two rounds. The response was diverse. The overall response was encouraging. Based on the response received, the average of each parameter and an overall average of strengths, weaknesses, opportunities, and threats were calculated with the RII tool.

2.2. Relative Importance Index (RII) Analysis

The Relative Importance Index (RII) analysis tool is used to highlight the most important attributes. RII analysis allows identifying the most important criteria based on participant's replies and it is also an appropriate tool to prioritize indicators rated on the Likert scale. Each point's remark is put in the RII equation. The RII method was adopted in this study to determine the relative importance of various factors affecting the quality of attributes.

The formula of RII in the literature is (Rooshdi et al., 2018)

$$R.I.I = \frac{\sum w}{A^{*}N} = (5n5 + 4n4 + 3n3 + 2n2 + 1n1) / 5^{*} N$$

Where RII = relative importance index; W = weighting given to by respondents (ranging from 1 to 5); A = highest weight (i.e. 5 in this case) and N = total number of respondents.

Table 1: Likert scale rating

Point	Remarks
1	Strongly disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly agree

2.3. SWOT Analysis

The SWOT analysis of wind energy is presented in Figure 2.

3. RESULTS AND DISCUSSION

3.1. Strengths

Huge resource potential. Pakistan is blessed with the abundant potential of wind power. The determined wind potential of the coastal belt of Pakistan is 43 GW. According to the National Renewable Energy Laboratory (NREL), Pakistan has 346 GW of wind energy potential for electricity production. The Wind energy potential in Pakistan is abundantly available in the country, especially in the coastal belt of Sindh and Baluchistan provinces of Pakistan with an average wind speed of 7 m/s at 50 m anemometer height.

- Accurate wind maps. The department of meteorology has developed wind maps of Pakistan. All the relevant data regarding wind energy is available to developers, investors, and policymakers. An assessment has been done by World Bank under the Energy Sector Management Assistance Program (ESMAP) to get validated biomass, solar, and wind maps of Pakistan. World Bank has issued 12 years map in phase 1 while using satellite and ground-based data. In the second phase, more sites have been established and wind measuring towers have been placed to collect the wind data throughout the country. In this way, after collecting two years of data, the World Bank will issue more accurate data and highly validated maps. This data will be available and will be very useful for wind energy developers, investors, and policymakers.
- Institutional framework. To promote renewable energy technologies, the government of Pakistan has established the Alternative Energy Development Board (AEDB). The mandate of AEDB is to provide all necessary support to investors and create the necessary infrastructure for the development of wind energy. The AEDB is facilitating the investors under one window operation. The one window operation has attracted many investors in the wind energy sector. Currently, Pakistan has a wind generation capacity of around 1200 MW and many wind projects are under various stages of completion. As per alternative and renewable energy policy 2019, the government of Pakistan has planned to enhance the share of renewable energy by 30% up to the year 2030. Wind power will play important role in renewable energy share.
- Emission-free. Since wind power does not burn any fuel hence there are no emissions. It produces zero carbon emissions. The zero carbon emissions can repay as a carbon footprint. In one of the findings conducted in 2018, wind turbines avoided 200 million tons of carbon pollution (AWEA, 2018). Wind energy helps to cut SOx, NOx which is toxic gases. These gases form acid rain and can damage vegetation and human health. These reductions in air pollution created 9.4 billion US dollars in public health saving in 2018 (AWEA, 2018). Therefore, wind energy is regarded as one of the cleanest sources of energy.
- Job creation. The development of renewable power has created enormous opportunities for job creation. The first annual assessment report issued by the International Renewable Energy Association (IRNA) states that eleven million people got jobs in the renewable energy sector in 2018 worldwide. These are 0.7 million more jobs as compared to 2017. Wind energy alone provided 1.2 million jobs globally. Pakistan is also promoting renewable energy, especially wind power, therefore many jobs are expected to be created. With more investment in wind energy, more jobs will be created.

Figure 1: Distribution of the Delphi survey participants according to their significance

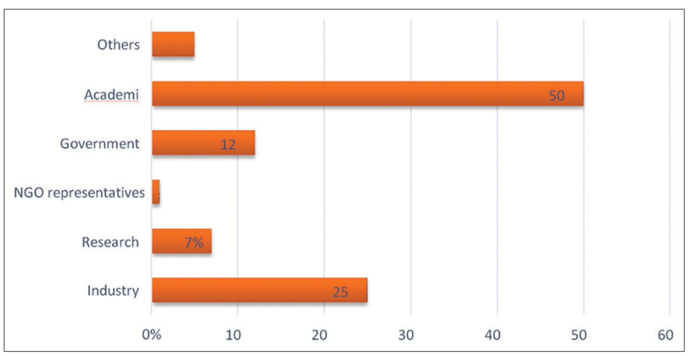
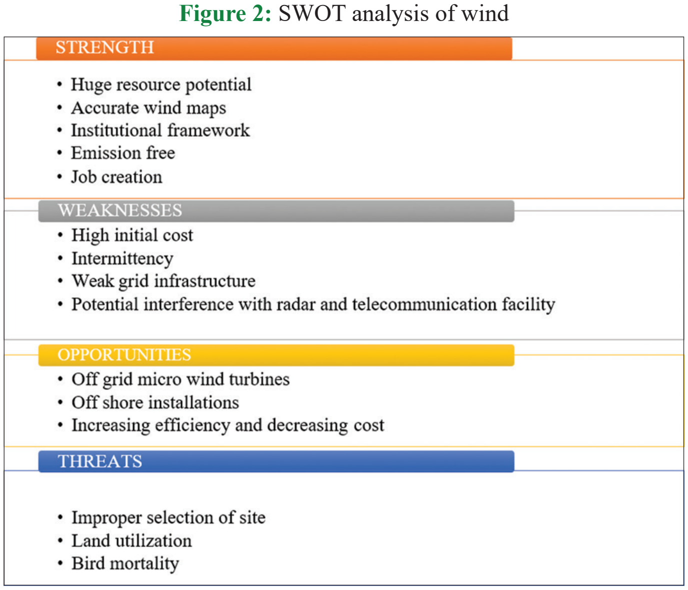


Figure 2: SWOT analysis of wind



3.2. Weaknesses

- High initial cost. The weaknesses of wind power are its high initial investment. This is one of the big hindrances to the development of wind energy generation. Although the prices of wind turbines have decreased dramatically over the last ten years, the technology requires a higher initial investment cost than fossil-fuelled power plants. Since complete installation requires wind turbines, foundation, grid connection, project development, and management. Around 80% of the cost of wind energy power consists of turbines. Moreover, the wind turbines are not manufactured in Pakistan, therefore the total cost of wind farms becomes costly.
- Intermittency. Intermittency of wind power is one of the main challenges in the way of wind power penetration in the power system. Wind speed is the main driver behind power intermittency as it varies with time. Therefore, electricity generated by wind turbines fluctuates. The power generated

by wind is not always available when required. Wind power cannot be handled and managed as any conventional power like a thermal, hydro, or nuclear power plant. Therefore, large-scale penetration can lead to impacts on power system stability, and operational security. Managing these challenges will result in higher costs. Therefore, wind power intermittency is a big challenge to add as a major player in the overall energy mix.

- Weak grid infrastructure. To evacuate wind power for the national grid, enough and adequate grid infrastructure is imperative. In Pakistan, weak and insufficient grid infrastructure is the main challenge in the development of wind energy projects. There are numerous issues such as difficult soil conditions, lack of funds, and inadequate transmission facilities (Building and Options 2016). To overcome these obstacles, private investment should be encouraged to strengthen existing grid infrastructure and introduce smart grid integrated technologies in the power system.
- Potential interference with radar and telecommunication facilities. In some cases, it has been observed that the signals of the telecommunication system have degraded due to the presence of wind farms. Since wind turbine is rotating part of wind power which can cause interference in signal processing leading to compromise on the quality of radar signals or any other telecommunication facility. This weakness can be mitigated by choosing any other alternative location either for a wind farm or telecommunication facility at the preliminary design stage.

3.3. Opportunities

- Off-grid micro wind turbines. In areas that are far from the national grid and enough wind is available, in such circumstances, the installation of a microgrid is a good option. There are many advantages of installing small wind farms such as it complements solar power, is a stable and passive investment, does help the environment, and relieves pressure on the national grid. Many areas in the Baluchistan province of Pakistan are airy, scattered, and far from the grid. These can be electrified through off-grid microturbines.
- Offshore installations. The speed of the wind is usually faster offshore than on land. A small increase in wind speed has a significant impact on power output. With an increase of 3 mph, a turbine would generate twice the energy. Faster wind speed means more power output. Wind offshore is more stable than onshore. Stable wind speed means more reliable power; it can supply to consumers or utilities. In Pakistan, around 22 million people are living in the coastal city of Karachi. Many other towns are situated on the coast of Balochistan. The energy needs of coastal cities are usually higher than those in other populations. Installing offshore wind farms can supply electricity to the nearby population more conveniently. Besides providing renewable energy, they provide jobs, do not emit greenhouse gases to the environment, and utilize domestic energy sources.
- Increasing efficiency and decreasing cost. The cost of wind power has decreased over the last ten years. The cost of a wind turbine is still decreasing, and the efficiency of the turbine shows an upward trend globally. Such a continuous trend can be seen in Figure 3.

3.4. Threats

- Improper selection of a site. The selection of a proper site is of paramount importance. Improper selection is a great threat to wind power generation. Sudden changes in the velocity and direction of the wind can cause serious consequences. Wind shear is a state in which the direction or speed of the wind is changed. This change is caused by highway flyovers, the surrounding landscape, the proximity of buildings, temperature inversions, and surface obstructions. Shear winds enter the turbine vertically up the appearance of the turbine on top of normal wind going through the blade arc. The blades are loaded with fluctuating loads, thus compromising the reliability and stability of power output.
- Land utilization. Lands occupied by wind farms include wind turbine pads, access roads, substations, service buildings, and other infrastructure which physically occupy a land area, or create impermeable surfaces (Denholm et al., 2009). Besides degradation caused by infrastructure development, there are direct impacts that are associated with development in forested areas, where additional land is required to be cleared around each turbine. While land cleared around a turbine pad does not result in impervious surfaces, this alteration represents a potentially substantial degradation in ecosystem quality. Loss of land utilization depends on the type of land. If the land is an agricultural, mining area, or forest land, then it must be cleared for the turbine as each turbine requires some clearing area.
- Bird mortality. It is reported that wind turbines may harm and kill birds. In the developed world, such studies have been conducted to quantify the loss of biodiversity in wind farms. The findings suggest that deployment of wind farms can have undesirable impacts upon biodiversity, collision mortality, dislocation from nesting or feeding areas, effects of a barrier to movement, and habitat destruction. The collision of birds and bats with a turbine blade is a matter of grave concern. In agrarian areas, a large number of birds have been reported to be killed by blades of wind turbines (Thaxter et al., 2017).

Figure 3: Increasing efficiency and decreasing cost of wind power (Bogmans, 2019)

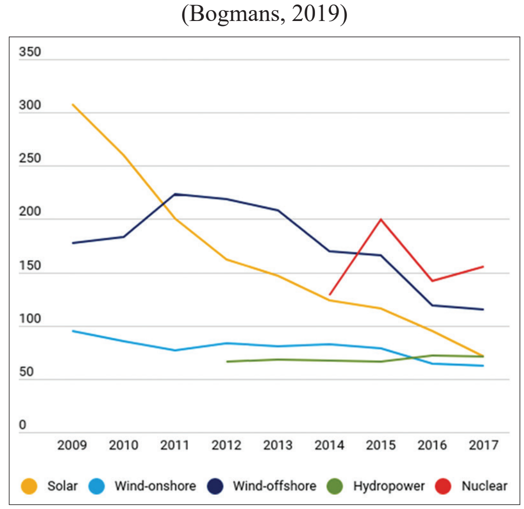


Table 2: Average values of strengths, weaknesses, opportunities, and strengths

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	No: of Respondents	R.I.I	R.I.I AVG
Strengths								
High resource potential	0	2	3	16	14	35	0.84	0.81
High validated solar maps	0	1	3	18	13	35	0.84	
The increasing interest of the private sector	1	3	6	15	10	35	0.77	
Minimum operation and maintenance cost	0	3	5	16	11	35	0.80	
Emission-free	0	1	4	17	13	35	0.84	
WEAKNESSES								
	Strongly Disagree (1)	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**	**Total Respondents**	**R.I.I**	**R.I.I AVG**
Capital investment	2	3	7	15	8	35	0.73	0.80
Lack of DC appliances	1	2	4	16	12	35	0.80	
Intermittency of solar irradiance in summer and winter	0	0	1	20	14	35	0.87	
Opportunities								
	Strongly Disagree (1)	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**	**Total Respondents**	**R.I.I**	**R.I.I AVG**
Grid parity achievement	0	2	7	18	8	35	0.78	0.77
Indoor photovoltaic	1	2	8	15	9	35	0.76	
Socio-economic acceptance	1	2	5	17	10	35	0.78	
Threats								
	Strongly Disagree (1)	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**	**Total Respondents**	**R.I.I**	**R.I.I AVG**
Lack of incentives for mini/micro installations	0	2	6	17	10	35	0.80	0.82
Conventional matured technology	0	1	5	19	10	35	0.81	
Lack of local manufacturing products	0	1	3	18	13	35	0.84	

Since no such study has ever been conducted to quantify the effects of wind farms on bird mortality, therefore there is a need to assess the mortality rate of birds and suggest some mitigating measures to reduce the loss (Table 2).

4. CONCLUSION AND POLICY RECOMMENDATIONS

Based on the SWOT analysis, it is found that Pakistan has high wind resource potential with accurate wind maps and institutional framework. The deployment of wind power will enhance energy security, environmental sustainability, and the creation of jobs. The major obstacles are weak grid infrastructure, policy implications, lack of consistency in government policies, and availability of funds. The RII analysis further validates the findings of SWOT that Pakistan cannot successfully deploy wind energy unless local manufacturing of wind turbines is encouraged with direct foreign investment and up-gradation of grid infrastructure.

4.1. Policy Recommendations

1. Encourage local manufacturing of wind turbines.
2. Incentives to the private sector to invest in wind power.
3. Improvement and up-gradation of grid infrastructure.
4. Enhance research and development funds for wind power.
5. Latest software to be deployed to monitor the exact wind data.
6. Empower the provinces in decision-making for wind power deployment and its operation.
7. Better scheduling, energy, and risk management techniques are required to increase wind power deployment in Pakistan.

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