Analysis of barriers to the adoption of cleaner energy technologies in Pakistan using Modified Delphi and Fuzzy Analytical Hierarchy Process

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Abstract

Pakistan has an enormous amount of renewable and sustainable energy sources. However, it is unfortunate that the country remains unsuccessful in using these sources to deliver increasing electricity demand. Studies attribute various barriers to this failure. However, little is known about the degree to which these barriers impede renewable energy (RE) in Pakistan. Therefore, the current study presents a systematic framework to prioritize barriers according to their importance. The study is divided into three phases. Firstly, barriers were identified using literature survey. Secondly, the Modified Delphi method was used to finalize and categorize barriers in the Pakistani context. Twenty-one barriers were finalized, which were then categorized under five main barriers, including, political and regulatory, market competitiveness, institutional, technical, and social. Finally, Fuzzy Analytical Hierarchical Process (FAHP) was employed to calculate weights and rankings of barriers and sub-barriers. The results revealed that political and regulatory barrier category ranks highest among major categories, whereas, overall ranking of barriers showed that political instability sub-barrier is more important than the rest of twenty sub-barriers within different categories.

Keywords: Renewable energy barriers; Energy crisis; Pakistan; Modified Delphi; FAHP

Highlights

- Identification and prioritization of renewable energy barriers in Pakistan;
- Twenty-one barriers were finalized and categorized under five major barriers;
- Political and regulatory category reported to be the most important major barrier;
- Political instability sub-barrier ranked top among overall sub-barriers.

1. Introduction

In today's world, electricity serves a variety of purposes ranging from lighting, cooling, refrigerating, and heating to operating computers, machinery, and other electrically-managed appliances. This wide use of electricity has multiplied the global electricity demand, which is projected to be double by 2050 (Bloomberg NEF, 2018).

Like other developing countries, Pakistan needs an uninterrupted, adequate, affordable, and sustainable energy supply to drive a wider economic growth to improve the living standards of its citizens and bring socio-economic prosperity. However, an acute electricity shortage stymies economic growth. Despite 99% electricity access rate, people do not get adequate and reliable electricity. There has been an awful load-shedding of 8-10 hours in urban to 18-22 hours in rural areas (Mirjat et al., 2018). This nationwide major power outage does not go down well with major economic sectors, which have been reporting huge losses due to the interrupted and insufficient electricity supply.

The stubborn energy shortage has its roots in the country's unimpressive power mix, which is overly dependent on fossil fuels. The problem with fossil fuels is that they are mostly imported and costly. Therefore, the weak economy of Pakistan cannot afford adequate supplies of imported fuels. As a result, additional electricity cannot be produced to meet the increasing demand. In such a scenario, renewable energy sources provide an excellent opportunity for Pakistan to increase its electricity supply. RE sources are globally recognized to be the best alternatives to fossil fuels for generating cost-effective, clean, and sustainable electricity.

Fortunately, Pakistan possesses some of the world's excellent renewable energy (RE) sources. A preliminary survey by the USAID and the National Renewable Energy Laboratory (NREL) reported that the coastal areas of Pakistan's Balochistan and Sindh provinces hold a colossal prospect of wind energy. In terms of solar energy potential, Pakistan is reported to have the best solar radiation receiving sites where sunshine remains for more than 10 hours a day. The world bank compares the solar radiation, received in the northern parts of Balochistan, with those received in the Middle East and North Africa region aka MENA, the world's top solar radiation receiving region (Shah et al., 2018). Being an agrarian country, Pakistan produces an abundant amount of agriculture residue, which can be used as a feedstock for biomass energy generation. The energy generation potential from geothermal energy and municipal solid waste is also available in the same fashion. (Kamran, 2018).

Despite this amazing potential, RE sources could not achieve any remarkable progress. Also, Pakistan has a RE policy in place since 2006. However, this policy has failed to attract any significant investment in the RE sector. As a result, the share of RE sources in electricity generation remains as low as one percent. Studies associate this low progress of RE sources to various barriers, which are to blame for being the hampering factors in RE development. (Kessides, 2013). Experts in the field also believe that unless these barriers are well understood and adequately addressed, the fate of RE sources in Pakistan shall remain the same. Thus, it becomes prerequisite to identify, analyze, and rank these barriers according to their importance in order to devise targeted solutions for these barriers.

Ghimire and Kim (2018) assessed RE barriers of Nepal. They used the analytical hierarchy process (AHP) as the main methodology to prioritize and rank RE barriers. Their study identified twenty-two barriers, which the authors categorized into six major categories, including social, administrative, geographic, political and policy, technical, and economic barriers. The study ranked political, and policy barrier as the top barrier category followed respectively by economic, geographic, administrative, social, and technical barriers.

Luthra et al. (2015) analyzed RE barriers in the Indian context. They also applied AHP as the main technique. Their study shortlisted twenty-eight barriers, which they categorized into seven categories. The results showed that the barriers under 'ecological and geographical' category have more influence on RE development. The rest of the barriers categories were ranked respectively as political and governmental, technical, economic and financial, awareness and information, cultural and behavioral, and market barriers. Heo et al. (2010) used Fuzzy AHP to assess the factors influencing renewable dissemination program in Korea.

RE barriers are contextual in nature. Therefore, their significance can vary from one country to another based on that country's technical potential, socio-economic, geographic, and political conditions. Lack of such investigation studies may contribute to the failure of RE policies. Thus, it is immensely important to understand the scope of barriers before formulating policies to address them.

To fill this gap in the literature, we conduct a thorough investigation of RE barriers in Pakistan. Our study first identifies RE barriers and then rank them according to the degree to which they hinder RE development in Pakistan. As such, the contribution of this study is manifold. The analysis presented in this study shall assist policymakers in designing more appropriate and comprehensive policies to address RE barriers. Extensive literature survey of RE barriers, provided in this study, can be helpful for researchers interested in studying the subject. The systematic framework developed in this study could be a guide for similar studies on RE barriers in other countries; however, the number of barriers and result may vary. The significant contribution of this study is that it shall help to cope with RE barriers and pave the way to increased RE deployment in Pakistan.

The analysis is divided into three parts. In the first part, an extensive literature is conducted to identify and compile RE barriers from past studies. In the second part, these barriers are finalized in the Pakistani context using the Modified Delphi method. Finally, Fuzzy Analytical Hierarchy Process (FAHP) is employed to calculate weights and rankings of major barriers, sub-barriers within major barriers, and overall sub-barriers. The traditional AHP can also be applied for this purpose, but the AHP sometimes gives biased results because it has an unbalanced scale of judgments. FAHP, on the other hand, is more proficient in dealing with uncertain and vague judgment involved in multi-criteria decision making (MCDM) process.

The remainder of this study proceeds as follows: Section 2 provides insights into Pakistan's energy crisis and role that cleaner energy technologies can play to overcome the crisis; Section 3 develops the methodological framework of the study; Section 4 finalizes barriers using Modified Delphi and conducts numerical analysis using FAHP; Section 5 presents results and discussion; Conclusion is provided in the final section.

2. Pakistan's energy crisis and RE as a sustainable source

2.1. Energy crisis

Pakistan is facing the worst energy crisis of her history. The severe energy crisis poses a serious threat to the country's fragile economy by slowing the pace of economic activities. The current demand for electricity is about 25, 000 MW whereas the supply hovers around 20,000 MW causing an electricity deficit of 5000 MW. This gap between electricity demand and supply widens more than 7000 MW in summers when the demand for electricity increases. Due to electricity shortfall, the whole country faces rolling blackouts or load-shedding, which led to power outages that can reach to 10-14 hours in urban areas and 16-18 hours in rural areas. Moreover, the increasing population rate, to make the situation worse, is expected to push electricity demand to 63,000 MW by 2030 (Yousuf et al., 2014). However, with the current energy policies, it is less evident that the slow-growing electricity supply would ever be able to match the increasing electricity demand (Hussain et al., 2016).

The current energy policies are skewed towards the thermal power generation. Various studies attributed over-reliance on fossil fuels, mainly furnace oil, as the prime reason for persistent power shortage. Shaikh et al. (2015) in their study of diagnosing energy crisis in Pakistan indicated that the root causes of electricity shortfall in Pakistan could be found in county's power mix, which is tilted towards expensive and imported fuels. Mirjat et al. (2017) highlighted that excessive reliance on thermal generation exacerbates the power sector's woes.

Currently, the bulk of electricity supply in Pakistan comes from fossil fuels. Fig. 1 shows the power mix of the country in 2017. It can be seen that the thermal generation was accounted for more than 60% of the total electricity generation. However, as reported, the country has very limited indigenous fuels reserves, and therefore, it needs to import most of the fuel used for electricity generation. On the other hand, the crippled economy of the country is unable to bear these huge import expenses and often fail to make timely payments to oil suppliers. In this wake, it is inevitable for Pakistan to address its energy crisis without adopting renewable and sustainable energy alternatives.

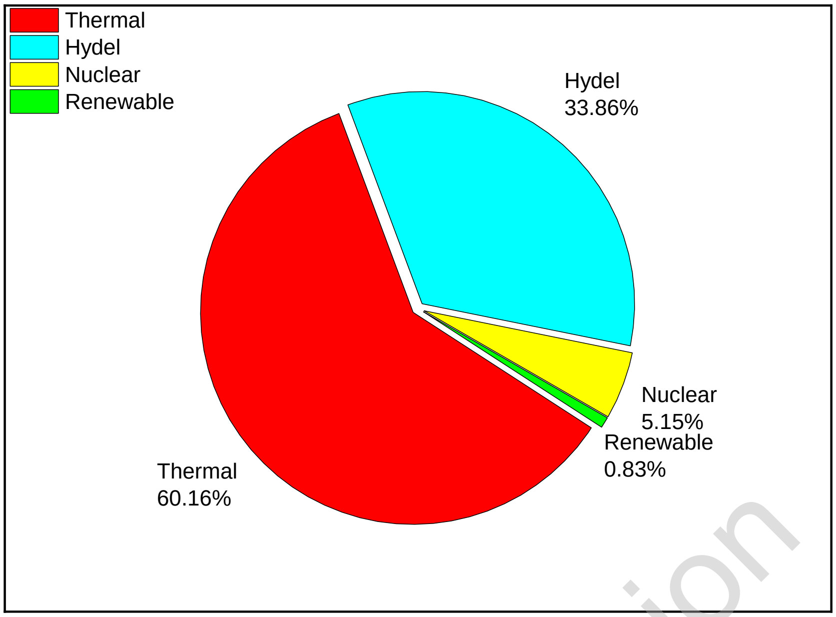

Fig. 1. Electricity mix of Pakistan in 2017 (NEPRA, 2017)

2.2. RE for Pakistan's energy crisis

The energy that we obtained from natural resources such as wind, solar, hydro, biomass, and geothermal is known as RE. Ever since the beginning of human civilization, these sources have been providing energy needs of human beings with almost zero greenhouse gases emission. These energy sources are abundantly available around the globe and can deliver the energy demand of the whole world (Jacobson et al., 2017).

Similarly, Pakistan also has a massive amount of RE sources, which can be utilized to meet the growing demand for electricity. The current total potential is estimated to be 167.7 GW, which is projected to be 287.5 GW by 2050 whereas, the current demand for electricity is only 25,000 MW, which is estimated to reach 63,000 MW by 2030 (Rafique and Rehman, 2017). The use of these renewables can not only increase the energy self-sufficiency but also spur sustainable economic growth and reduce harmful emission to tackle climate change (Lin and Raza, 2019). Utilization of renewables shall create new employment opportunities and new local industries for the manufacturing of RE equipment.

RE technologies, therefore, came to the forefront in national planning and policy making. The government of Pakistan had issued a white paper in 2005 which aimed to obtain at least 10% of required electricity from renewables by 2012. However, no RE capacity could be added to the grid until 2008. The government then revisited the targets in 2008 and devised a new target of adding 5% from RE by 2030 (Farooq and Kumar, 2013). Since then, the government has been offering various fiscal and financial incentives to attract investment in this sector. Fiscal benefits include tax exemption on importing RE-related machinery and equipment, and financial benefits include the permission given to power producers for issuing corporate bond and shares.

Since 2015, the installed capacity of RE sources crossed 1200 MW, including nearly 600 MW of wind power, 400 MW of solar PV, 160 MW of biomass, and 50 MW of mini hydropower. Other RE projects which are currently under development stage will add nearly 2000 MW. However, in order for renewables to address the decades-long energy crisis, more efforts are required from the government to expedite RE deployment as a tremendous amount of wind, solar, and biomass is yet to be exploited.

3. Research framework

A systematic approach was adopted to complete this research. Firstly, we conducted an extensive literature review of related studies to find out the barriers. After that, we used a modified Delphi method to finalize and categorize RE barriers in the context of Pakistan. Later, FAHP was employed FAHP to assign weights to barriers and then rank them according to their importance. Fourteen relevant experts participated during Delphi and FAHP processes. These experts included four university professors, five senior research fellows, two board members of the RE institute in Pakistan, and three investors. The research design of the current study is shown in Fig. 2.

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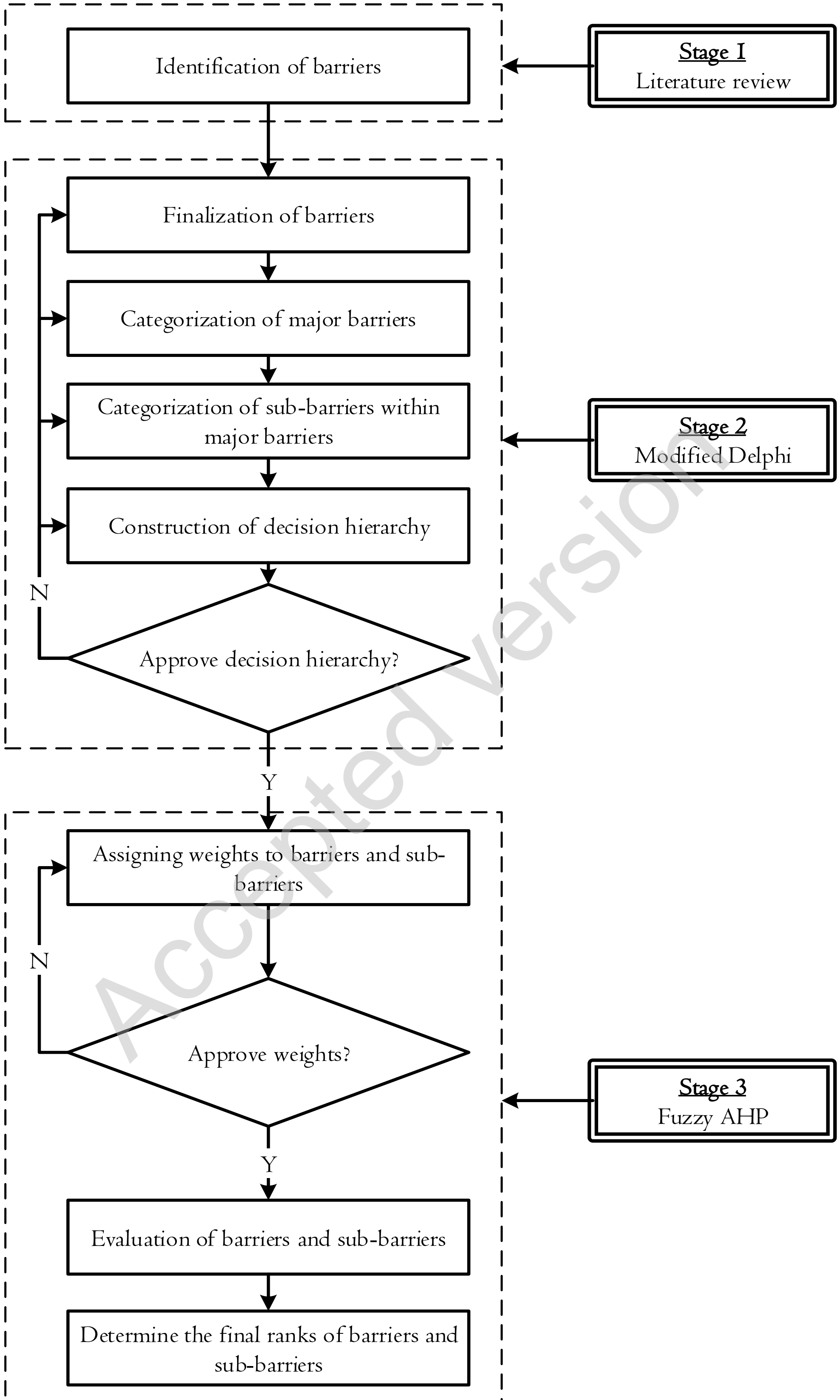

178 **Fig. 2.** The research design of the current study

3.1. Modified Delphi

The Modified Delphi method is applied to finalize and categorize RE barriers. This method is a systematic way to collect experts' feedback through group discussions and questionnaires. In this method, experts from the relevant field share their ideas, knowledge, opinions, and expertise to make mutual assumptions (Chang et al., 2008; Hsu et al., 2008; Lummus* et al., 2005). Five steps are involved in this method for reaching mutual consensus, i.e., experts selection; the first round of survey; the second round of questionnaire survey; the third round of questionnaire survey; compile experts' feedback. Steps 3 and 4 are repeated until the decision-makers reach mutual consent (Sung, 2001).

Literature does not provide any mandatory number of experts that must be chosen for this method. Different studies proposed different rules to consider while selecting the number of experts. Few studies recommended that 10 experts are sufficient to receive reliable results (Bouzon et al., 2016). Robbins et al. (1993) advised that the number of experts remains between 5 to maximum 50. Murry Jr and Hammons (1995) concluded that opinions from 10 to 30 experts are necessary to ensure the best results. Okoli and Pawlowski (2004) suggested that the modified Delphi method can effectively collect and summarize 10 to 18 expert's opinion. Therefore, in this study, 14 energy experts participated.

3.2. FAHP

The AHP was introduced by Saaty (1988). It is one of the most widely used multi-criteria decision-making models to solve complex and multifaceted decision-making problems (Sun, 2010). AHP is used to quantify decision makers' relative priorities for a set of alternatives on a ratio scale. This model underscores the importance of decision-makers' instinctive judgments and consistency of comparing alternatives during the decision-making process. The method can be combined with other techniques, such as data envelop analysis, fuzzy theory, mathematical programming, and metaheuristics (Ho, 2008).

Although AHP can be applied to quantify decision makers' judgment, however, the method lacks in reflecting the human way of thinking. This is because traditional AHP has some limitations, such as (1) dealing with unbalanced judgmental scale (2) unable to handle ambiguity and uncertainty associated with drawing of one's judgment to a number (3) imprecise ranking and (4) subjective judgment; decision makers' preference greatly influences AHP results.

Therefore, Saaty's AHP was extended into FAHP, which is extensively used and more powerful technique to deal with the uncertainty and vagueness involved in decision-makers' feedback. FAHP combines traditional AHP with the Fuzzy set theory in which the membership of an element is defined by a membership function. The membership function maps fuzzy decision elements into degrees of membership, which is usually between [0,1]. Any element with a "0" value has no membership. Conversely, elements with "1" value have full membership. Elements that lies between "0" and "1", hold a certain degree of membership (Chang, 1996). Thus, the membership function converts linguistics terms into fuzzy numbers so that the uncertainties involved in the logistic estimation process can be handled effectively. Practically, the triangular fuzzy number (TFN) is used to represent linguistics values as fuzzy numbers.

Due to mentioned benefits of FAHP in dealing with uncertain and imprecise judgments by handling linguistic variables, the method is widely used to solve multi-criteria decision-making problems in a variety of fields, e.g. selection of thermal power plants (Choudhary and Shankar, 2012), supplier selection in automotive industry (Jain et al., 2018), assessment the success of sustainable human resources management (Tooranloo et al., 2017), measuring healthcare services (Singh and Prasher, 2019), ranking the solution to the adoption of knowledge management in supply chain (Patil and Kant, 2014), selection of relevant sustainability issues in strategic decision-making (Calabrese et al., 2019), risk evaluation (Fattahi and Khalilzadeh, 2018), selection of networks in heterogeneous wireless networks (Goyal et al., 2018), modeling the barriers of pharmaceutical supply chain (Vishwakarma et al., 2019), selection of energy conversion technologies for agricultural residue (Wang et al., 2019), prioritization of corporate social responsibility drivers in the footwear industry (Moktadir et al., 2018), assessment of risk involved in onshore photovoltaic electricity generation projects (Wu et al., 2019) and so on.

To rank renewables energy barriers in Pakistan, FAHP was employed in the following six steps:

Step 1: Developing the hierarchical structure of the problem.

Step 2: Describing the scale of relative importance employed in pairwise comparison matrix.

After developing the hierarchical tree, the method proceeds by defining the scale of relative importance for the pairwise comparison matrix. TFNs from $\tilde{1}$ to $\tilde{9}$ were used to enhance conventional nine-point scale (see Table 1). To capture vagueness involved in experts' qualitative assessment, five TFNs ($\tilde{1}$, $\tilde{3}$, $\tilde{5}$, $\tilde{7}$, $\tilde{9}$) were employed with their corresponding membership. Fig. 3 shows a fuzzy membership function for criteria and sub-criteria.

Table 1. Linguistic values and TFNs for criteria

Linguistics values	Triangular fuzzy numbers	Fuzzy number	AHP Equivalent
Extreme importance/preference	(7,9,11)	$\tilde{9}$	9
Very strong importance/preference	(5,7, 9)	$\tilde{7}$	7
Strong importance/preference	(3 ,5,7)	$\tilde{5}$	5
Moderate importance/preference	(1,3,5)	$\tilde{3}$	3
Equal importance/preference	(1,1,3)	$\tilde{1}$	1

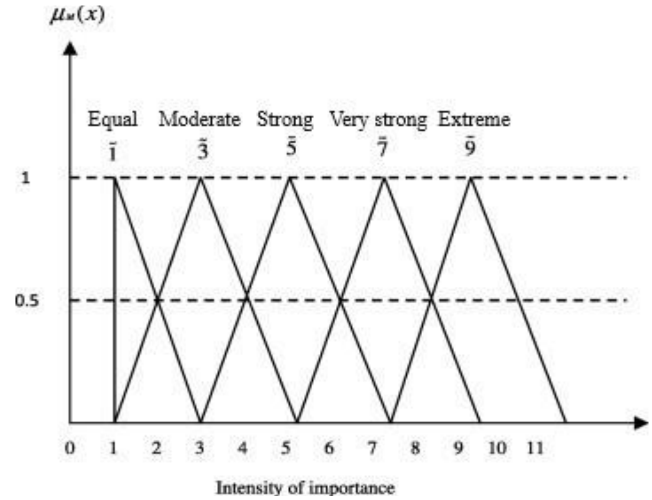

Fig. 3. Fuzzy membership function for linguistic variables (Nepal et al., 2010)

Step 3. Constructing a fuzzy comparison matrix

The experts were asked to make a pairwise comparison for the criteria and sub-criteria using TFNs. Based on the arithmetic mean of pairwise comparison from the experts, following fuzzy comparison matrix $\tilde{A}$ is drawn.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \dots & \tilde{a}_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \dots & 1 \end{bmatrix} \tag{1}$$

Where $\tilde{a}_{ij} = 1$, if $i = j$, and $\tilde{a}_{ij} = (\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9})$ or $(\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1},)$ if $i \neq j$. When scoring is calculated for a pair, a reciprocal score is automatically given to reverse comparison in the matrix. That is, if $\tilde{A}_{ij}$ is a matrix value given to the relationship of components i and j, then $\tilde{A}_{ij} = \frac{1}{\tilde{A}_{ij}}$.

Step 4. Conversion of fuzzy comparison matrix into the crisp comparison matrix

An α-cut method was proposed by Adamo (1980) to rank fuzzy numbers. The method is used to incorporate decision-makers' confidence in their judgment. It yields an interval set of values from a fuzzy number. For instance, $a = 0.5$ will yield $a_{0.5} = (2{,}3{,}4)$ (see Fig. 4).

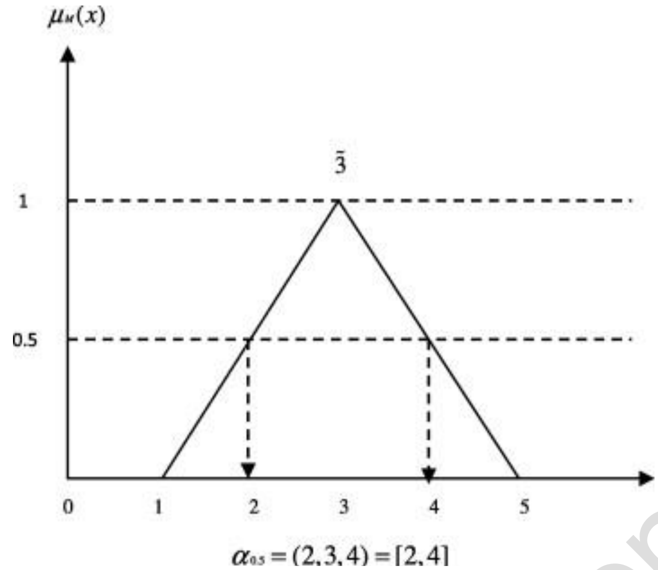

Fig. 4. α-cut operation on TFN

While α is fixed, and the index of optimism μ is set to estimate the degree of satisfaction, the following α-cut comparison matrix can be constructed from a fuzzy comparison matrix.

$$\tilde{A}^{\alpha} = \begin{bmatrix} 1 & \tilde{a}_{12}^{\alpha} & \dots & \dots & \tilde{a}_{1n}^{\alpha} \\ \tilde{a}_{21}^{\alpha} & 1 & \dots & \dots & \tilde{a}_{2n}^{\alpha} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \tilde{a}_{n1}^{\alpha} & \tilde{a}_{n2}^{\alpha} & \dots & \dots & 1 \end{bmatrix} \quad (2)$$

The index of optimism μ, determined by the decision makers, estimates the degree of satisfaction for preference matrix. The larger the value of μ, the higher the degree of optimism. The index of optimism μ is a linear convex combination as described in the subsequent equation (Lee et al., 1999).

$$\tilde{a}_{ij}^{\alpha} = \mu a_{iju}^{\alpha} + (1-\mu) a_{iju}^{\alpha} \text{ where } 0 < \mu \leqslant 1 \quad (3)$$

The α-cut fuzzy comparison matrix is transformed into crisp comparison matrix A by putting the value of μ in Eq. 3.

$$A = \begin{bmatrix} 1 & a_{12} & \dots & \dots & a_{1n} \\ a_{21} & 1 & \dots & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & \dots & 1 \end{bmatrix} \quad (4)$$

Step 5. Consistency check

Consistency of each matrix and the overall consistency of hierarchy is calculated using the consistency ratio (CR). It should be noted that only a consistent crisp comparison matrix A shall result in a consistent fuzzy comparison matrix $\tilde{A}$.

Largest Eigenvalue of the matrix is calculated using Eq. 5.

$$A_p = \lambda_{\max} p \quad (5)$$

Where p is the principle Eigenvector of the matrix.

The CR is used to calculate the consistency of pairwise comparisons using Eq. 6.

$$CR = \frac{CI}{RI} \quad (6)$$

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (7)$$

where CI is the consistency index, RI is the random index (shown in Table 2), and n is the size of the matrix.

Table 2. Random Index

$\boldsymbol{n}$	1	2	3	4	5	6	7	8
$\boldsymbol{RI}$	0	0	0.52	0.89	1.11	1.25	1.35	1.40

As per the rule, when the CR of any matrix is less than 0.10, only then it is considered acceptable. Otherwise, the experts need to revise given values in the pairwise comparison matrix.

Step 6: Calculating the weights of criteria

The weights of all the criteria shall be computed by normalizing any of the columns or rows of matrix A.

4. Case analysis

4.1. Barriers finalization using Modified Delphi

An extensive literature review was conducted to shortlist barriers in the context of Pakistan. The keywords used to search RE barriers include “renewable energy barriers in Pakistan,” “renewable energy issues in Pakistan,” and “renewable energy challenges in Pakistan.” The major search engines we used to explore RE barriers in Pakistan are Google Scholar, Science Direct, and Google. Twenty-one RE barriers in the Pakistani context were finalized using Modified Delphi. These barriers were then categorized under five major barriers, i.e., Political and regulatory barriers, social barriers, technical barriers, financial barriers, and institutional barriers. Five sub-barriers were identified under the political and regulatory category, six sub-barriers under technical barriers, two under institutional barriers, three under social barriers, and five under market competitiveness. The classification of these barriers is delineated in Table 3, and a brief description of each barrier follows.

Table 3. Classification of RE barriers in Pakistan

Major barrier	Major barrier Code	Sub-barriers	Sub-barrier Code	References
Political and regulatory barriers	B-1	Inadequate regulatory framework	B-11	(Malik, 2007), (Mirza et al., 2009), (Kessides, 2013), (Mirza et al., 2007)
		Absence of coherent RE policy	B-12	(Sheikh, 2010), (Kessides, 2013), (Mirza et al., 2009)
		Political instability	B-13	(Mirza et al., 2009), (Farooqui, 2014), (Khan and Pervaiz, 2013)
		Corruption and nepotism	B-14	(Farooq et al., 2013), (Farooq et al., 2013)
		Lengthy regulatory approval and permit procedures	B-15	(Mirza et al., 2009), (Kessides, 2013)
Market competitiveness	B-2	High upfront cost	B-21	(Sheikh, 2010), (Yazdanie et al., 2010), (Mirza et al., 2009), (Farooqui, 2014)
		Lack of subsidies on renewables	B-22	(Mirza et al., 2009), (Yazdanie et al., 2010)
		Fossil fuels subsidies	B-23	(Mirza et al., 2009), (Kessides, 2013), (Yazdanie et al., 2010)
		Unfavorable electricity prices	B-24	(Yazdanie et al., 2010)
		Lack of access to	B-25	(Mirza et al., 2009), (Mirza et al., 2007)

		credit/funds		
Institutional barriers	B-3	Lack of institutional coordination	B-31	(Hassan et al., 2017), (Khattak et al., 2006), (Mirza et al., 2009), (Sheikh, 2010), (Yazdanie et al., 2010), (Mirza et al., 2007)
		Lack of Institutional Capacity	B-32	(Khattak et al., 2006), (Hassan et al., 2017), (Mirza et al., 2009), (Sheikh, 2010)
Technical barriers	B-4	Inadequate technology	B-41	(Mirza et al., 2009), (Shah et al., 2011), (Khan and Pervaiz, 2013)
		Lack of skilled manpower	B-42	(Gabriele, 2004), (Mirza et al., 2009), (Yazdanie et al., 2010)
		Lack of local manufacturing units	B-43	(Khan11 et al., 2012), (Mirza et al., 2009), (Sheikh, 2010)
		Lack of infrastructure	B-44	(Framework, 1994), (Shakeel et al., 2016), (Mirza et al., 2009), (Kessides, 2013), (Farooqui, 2014)
		Lack of R&D facilities	B-45	(Qudrat-Ullah, 2005), (Mirza et al., 2009)
		Lack of O&M facilities	B-46	(Gabriele, 2004), (Mirza et al., 2009), (Sheikh, 2010), (Yazdanie et al., 2010)
Social barriers	B-5	Lack of public awareness	B-51	(Mirza et al., 2009), (Mirza et al., 2007), (Yazdanie et al., 2010), (Shah et al., 2011)
		Lack of social acceptance	B-52	(Mirza et al., 2009), (Yazdanie et al., 2010), (Khan and Pervaiz, 2013)
		Lack of customer paying capacity	B-53	(Mirza et al., 2009)

4.1.1. Political and regulatory barriers (B-1)

Effective policy design and regulatory framework are essential to encourage the deployment of RE generation. Because the development of the RE industry in Pakistan is at its developing stage, it is particularly vulnerable to regulatory and policy shocks compared with other more established industries. So, the substantial political and regulatory barriers have decreased the efficacy of a rigorous national effort to install renewables. These barriers include ineffective regulatory framework, deficient policies, and lack of political determination to deploy renewables.

Inadequate regulatory framework (B-11): Commercial viability of RE technologies largely depends upon regulatory intervention and is expected to do so, at least until the competitiveness of RE and institutional experience increase. However, the absence of an effective regulatory structure hinders RE investment and poses a significant barrier to RE development in Pakistan. Lack of awareness among regulators and the exclusion of RE issues into regulatory policies inhibit private investment. Other regulatory issues prevailing includes unfavorable, unwieldy, and inadequate regulations to promote RE technologies.

Absence of coherent RE policy (B-12): Complexities in RE policy leads to burdensome compliance requirements for renewable electricity market participants and makes it hard for the new investors and technologies to integrate. A developing country like Pakistan does not have comprehensive and coherent RE policies which lead to delay in the allotment and clearance of private sector projects. This hinders private investment because enabling and clear policies create a stable and predictable environment for investors. Also, a considerable amount is required for large scale RE projects. Therefore, absence or lack of policy measures fail to attract private investors.

Political instability (B-13): Pakistan has a long history of political conflicts. Frequent changes in the government have adversely affected the energy sector. Many promises to increase energy supply remain unfulfilled because energy projects initiated by the departing government do not seek much attention of the succeeding government. Also, different governments have divergent priorities and mindsets; RE development may not necessarily be the priority of every government.

Corruption and nepotism (B-14): Like other developing countries, corruption and nepotism are Pakistan's dominant problems. It is nearly impossible in the country to do business, either with the government or without, unless the investors have made relationships with corrupt officials. The recent emphasis on RE development in Pakistan attracts the criminal appetite of politicians and officials, which dramatically influences the licensing process of RE projects, making them accessible to only those investors that successfully bribe.

Lengthy regulatory approval and permit procedures (B-15): Experts also cited lengthy permit procedure and regulatory approvals as a potential hindrance. A large number of organizations, involved in the process, and incomplete information about the permit and legal appeal process, also delay project execution.

4.1.2. Market competitiveness (B-2)

Lack of competitiveness of RE with conventional power generators seems a fundamental reason behind the modest growth of renewables in the Pakistani market. Despite the fact that renewables are provided tax benefits, electricity generated from renewables is moderately costlier than electricity generated from conventional sources. Barriers that influence the competitiveness of renewables in the market include high upfront, lack of subsidies on renewables, fossil fuel subsidies, unfavorable electricity prices, and the monopolistic nature of the market.

High upfront cost (B-21): The most apparent and extensively publicized barrier to RE technologies is cost – specifically, upfront or capital cost of building and installing RE projects. The high initial cost of developing RE projects compared to conventional energy projects decreases renewables' competition in the market as investors opt less expensive alternative so that they could maximize their profits. Also, higher initial costs might lead financial institutions to perceive renewable energies as risky, providing loans at higher rates, and making it more difficult for investors to justify the investment. Similar to other developing countries, investors in Pakistan are more likely to hesitate to invest in RE technologies due to high upfront.

Lack of subsidies on renewables (B-22): Renewable energies do not get more in subsidies than conventional energy sources have gotten and continue to get. Lack of subsidies makes renewable less competitive as compared to conventional electricity. Therefore, political support in terms of subsidy incentive is strongly needed to alleviate the high capital cost.

Fossil fuels subsidies (B-23): Provision of high levels of subsidies on the establishment and operational costs of fossil fuels raise unfair competition to RE technologies. Consequently, RE technologies become weak economically to compete subsidized conventional electricity in the markets. This means that due to many incentives to obtain fossil fuels than RE technologies, most of the people prefer to use conventional electricity than switching towards renewable energies.

Unfavorable electricity prices (B-24): Electricity tariffs on fossil fuels energy are meager and thus cause an unequal playing field for RE technologies. The external costs of fossil fuels (e.g., ecological cost) are not reflected in their prices. On the other hand, RE technologies' environmental benefits are not including while setting their prices. Thus, due to unfavorable pricing, RE technologies seems to be an expensive alternative in the eyes of customers. This leads to a negative perception of RE technologies and represents a definite hindrance for the development of RE technologies.

Lack of access to credit/funds (B-25): RE technologies in Pakistan are at a very developing stage, and only a few financial institutions offer funds to establish RE projects. The lack of access to credit facilities leads institutions to lend on higher rates. Moreover, limited access to simple credit schemes cripples the willingness of small investors to invest in new technologies.

4.1.3. Institutional barriers (B-3)

Institutional barriers are cited as a serious obstacle by stakeholders in the way of modern renewables' large-scale market growth. These barriers are as follows:

Lack of institutional coordination (B-31): Like other developing countries, Pakistan also encounters poor coordination and lack of harmony among different institutions involved in the planning and development of renewables. Various government agencies such as the Alternative Energy Development Board (AEDB) and Pakistan Council of Renewable Energy Technologies (PCRET) pursue their strategies in an uncoordinated manner (Hassan et al., 2017). Lack of institutes' consensus and unity over renewable policies result in a lack of commitment to implement renewable projects (Khattak et al., 2006). Further, lack of knowledge sharing among government institutes leads to failure of RE policies.

Lack of institutional Capacity (B-32): Many policymakers in institutions do not seem to be fully aware of the benefits and characteristics of RE. There is a strong need to strengthen the capacity building of institutions so that they can identify and address issued related to RE development.

4.1.4. Technical barriers (B-4)

Technical barriers include inadequate technology, insufficiency of technical manpower, the absence of systematic research and development, lack of infrastructure, including grid connection mechanism, and lack of operation and maintenance facilities necessary to support RE technologies.

Inadequate technology (B-41): Inadequate technology is identified as one of the significant barriers to the willingness to invest in renewable electricity. Lack of state-of-the-art technology is available in the market, which disappoints customers' expectations. The absence of technical standards, certificates, and codes, and their enforcement is a common issue in the country.

Lack of skilled manpower (B-42): Sufficient skilled personnel to manage and operate RE technologies are required for a successful RE structure. Due to inadequately trained manpower, especially in areas with low levels of education, people are unwilling to install RE technologies for fear of failure (Gabriele, 2004). In Pakistan, most of the local technicians and end-users are not familiar with RE technologies' sophistication level and thus do not know how to deal with these technologies.

Lack of local manufacturing units (B-43): Due to the absence of local manufacturing of RE technologies, the equipment must be imported, which further increases the cost of renewables, making them less competitiveness.

Lack of infrastructure (B-44): Poor and non-existent infrastructure is a significant challenge for a developing country like Pakistan. Inadequate grid connectivity poses a severe threat to the development of renewable energies, especially in remote areas. Deficient transmission and dispatch network is unable to transport safe and reliable renewable electricity from production point to end-users. The current infrastructural setup has the capacity to transmit only half of the required electricity, and any further load leads to system collapse; this frequently happens during peak hours (Shakeel et al., 2016). Investors lose their confidence in RE technologies due to lack of infrastructural support, which hinders their willingness to invest in renewable energies.

Lack of research and development (R&D) facilities (B-45): The absence of R&D culture and facilities lead to a lack of opportunities for manufacturing RE technologies within the country. No prominent research system in the field of renewable energies actually impedes the development in the renewable sector.

Lack of operation and maintenance (O&M) facilities (B-46): Lack of after-sales services and maintenance lower customer's confidence in RE technologies and thus hamper their adoption. This is because Pakistan imports most of the RE equipment, and thus, lack of spare parts availability and ample skills to repair or service the equipment result to the failure of equipment or affect its energy output. Many customers, therefore, choose fossil fuels since they are reliable and readily available (Gabriele, 2004).

4.1.5. Social barriers (B-5)

Social barriers deal with social perceptions and conditions associated with RE technologies. These barriers include conditions arising from cultural/contextual perceptions of a specific set of population. Unlike developed countries, social barriers in Pakistan significantly hold back RE progress. The following social barriers are identified as having a negative impact on RE development in Pakistan.

Lack of public awareness (B-51): Majority of the population in Pakistan reside in rural areas where the literacy rate is substantially low compared to urban areas. People residing in such areas are mostly unaware of the advantages of RE for the community. Also, people in urban areas do not have sufficient knowledge regarding the concept of renewables. This is mainly due to the absence of awareness campaigns for educating people regarding the concept and advantages of RE technologies. So, there is a lack of demand for renewables as alternative sources of electricity.

Lack of social acceptance (B-52): The concept of social acceptance was largely ignored in the past; however, very recently, it is considered vital for the development of the renewable industry. Like other developing countries, the “not in my backyard” phenomenon also exists in Pakistan, particularly regarding the large-scale wind farms.

Lack of customer paying capacity (B-53): Majority of the population in Pakistan live in rural areas and do not have access to electricity. The off-grid renewable electricity generation provides a better opportunity for these underserved population. However, the economic condition of these people is quite low as most of them are living below the poverty line and cannot afford expensive RE technologies. In order to utilize RE technologies for off-grid electrification, the government must support people to purchase modern and clean technologies.

4.2. Assign and compute weights of barriers using FAHP

Development of the hierarchical structure is the initial step of FAHP. Fig. 5 shows the hierarchical structure of RE barriers.

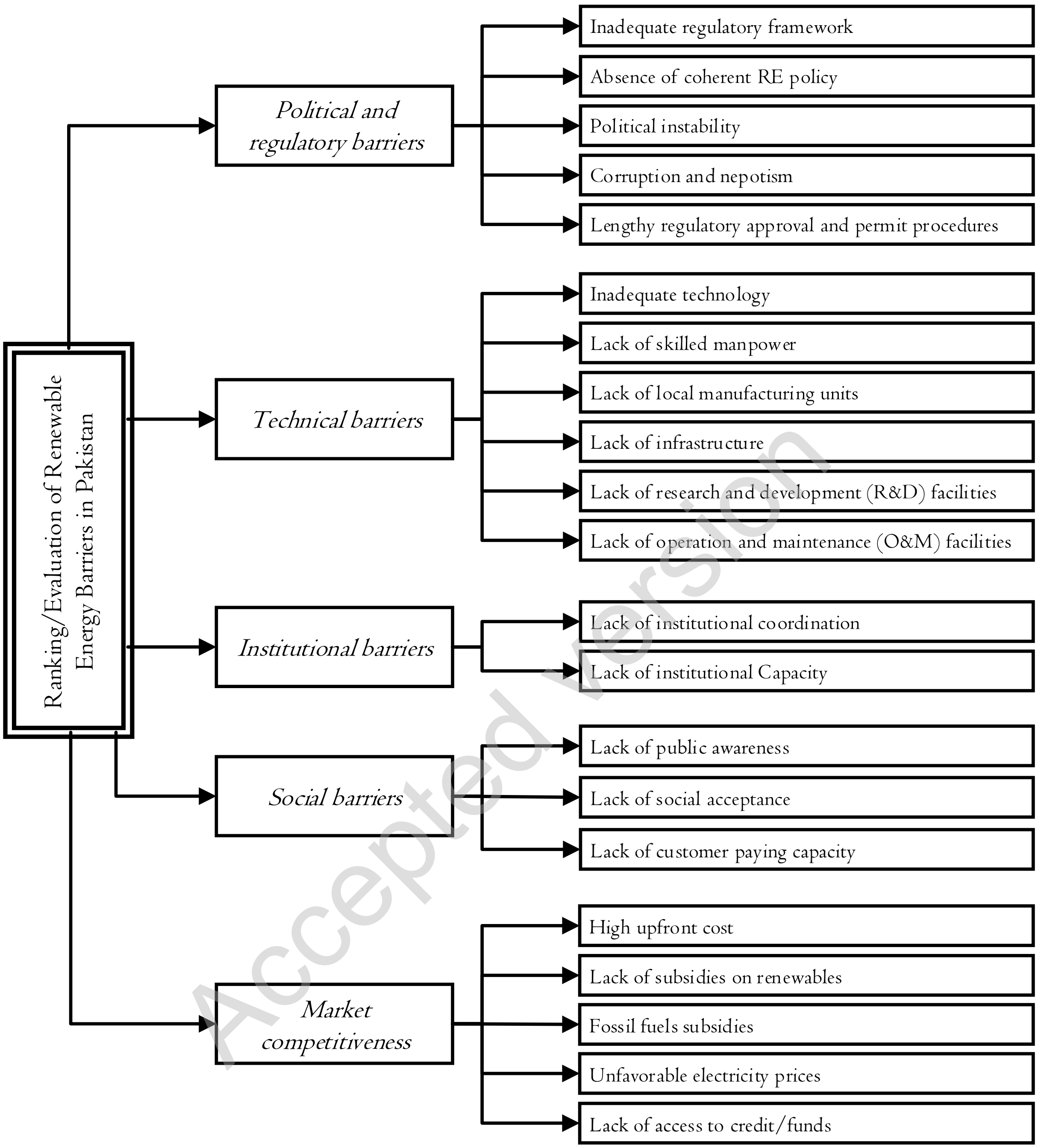

Fig. 5. The hierarchical structure of the problem

After developing the hierarchal structure, pairwise comparison matrices of major barriers and sub-barriers were constructed, which are provided in Tables 4-9. Finally, these pairwise matrices were solved to obtain the results, which are presented and discussed in the following section.

Table 4. Pairwise matrix of major barriers

	B-1	B-2	B-3	B-4	B-4
B-1	1,1,1	0.85,1.15,1.56	1.4,1.86,2.41	0.95,1.25,1.64	0.85,1.15,1.56
B-2	0.64,0.87,1.18	1,1,1	1.19,1.65,2.19	0.77,1.01,1.37	1.25,1.6,2.07
B-3	0.41,0.54,0.71	0.46,0.61,0.84	1,1,1	0.47,0.63,0.86	0.78,1.03,1.34
B-4	0.61,0.8,1.05	0.73,0.99,1.31	1.16,1.58,2.13	1,1,1	0.96,1.3,1.71
B-5	0.64,0.87,1.18	0.48,0.63,0.8	0.75,0.97,1.28	0.59,0.77,1.04	1,1,1

Table 5. Pairwise matrix of Political and regulatory barriers

	B-11	B-12	B-13	B-14	B-15
B-11	1,1,1	0.53,0.7,0.91	0.69,0.91,1.18	0.59,0.77,1.04	0.71,0.91,1.17
B-12	1.1,1.43,1.87	1,1,1	0.58,0.77,1.04	0.83,1.06,1.37	1.03,1.38,1.8
B-13	0.85,1.09,1.44	0.96,1.31,1.72	1,1,1	1.05,1.44,1.89	1.04,1.39,1.8
B-14	0.96,1.3,1.71	0.73,0.94,1.21	0.53,0.69,0.95	1,1,1	1.1,1.56,2.09
B-15	0.85,1.1,1.41	0.55,0.72,0.97	0.56,0.72,0.96	0.48,0.64,0.91	1,1,1

Table 6. Pairwise matrix of Market competitiveness barriers

	B-21	B-22	B-23	B-24	B-25
B-21	1,1,1	0.85,1.11,1.5	1.07,1.53,2.13	1.05,1.36,1.75	1.1,1.44,1.86
B-22	0.67,0.9,1.18	1,1,1	0.54,0.69,0.9	0.88,1.17,1.5	0.63,0.84,1.14
B-23	0.47,0.65,0.93	1.11,1.44,1.86	1,1,1	0.9,1.16,1.49	0.91,1.16,1.48
B-24	0.57,0.74,0.95	0.67,0.86,1.13	0.67,0.86,1.11	1,1,1	0.55,0.73,1
B-25	0.54,0.69,0.91	0.88,1.19,1.58	0.67,0.86,1.1	1,1.37,1.82	1,1,1

Table 7. Pairwise matrix of Institutional barriers

	B-31	B-32
B-31	1,1,1	0.9,1.15,1.47
B-32	0.68,0.87,1.12	1,1,1

Table 8. Pairwise matrix of Technical barriers

	B-41	B-42	B-43	B-44	B-45	B-46
B-41	1,1,1	1.19,1.65,2.19	1.16,1.58,2.13	0.55,0.71,0.95	0.96,1.3,1.71	1.25,1.6,2.07
B-42	0.46,0.61,0.84	1,1,1	0.67,0.86,1.12	0.66,0.87,1.15	1.03,1.28,1.6	0.69,0.9,1.22
B-43	0.47,0.63,0.86	0.89,1.17,1.5	1,1,1	0.73,0.99,1.31	0.79,1.02,1.31	0.74,1.01,1.37
B-44	1.05,1.4,1.82	0.87,1.15,1.5	0.77,1.01,1.37	1,1,1	1.29,1.73,2.25	1.25,1.67,2.21
B-45	0.59,0.77,1.04	0.7,0.88,1.11	0.76,0.98,1.27	0.44,0.58,0.78	1,1,1	0.56,0.76,1
B-46	0.48,0.63,0.8	0.82,1.11,1.45	0.73,0.99,1.35	0.45,0.6,0.8	1,1.32,1.79	1,1,1

Table 9. Pairwise matrix of Social barriers

	B-51	B-52	B-53
B-51	1,1,1	1.43,1.95,0.91	1.21,1.58,
B-52	0.51,0.7,0.99	1,1,0.65	0.91,1.27,
B-53	0.63,0.82,1.1	1.1,1.55,1	1,1,

5. Results and Discussion

5.1. Main barriers

The pairwise matrix given in Table 4 was solved to obtain weights and ranking of major barriers. Fig. 6 shows the results of main barriers. It can be seen that Political and Regulatory (B-1) category got the highest weight (0.245) and has been ranked as the most important in impeding RE development in Pakistan. This finding aligns with a recent study conducted to rank RE barriers in Nepal (Ghimire and Kim, 2018). The authors reported that policy and political barriers are the most affecting RE barriers.

Market Competitiveness (B-2) ranked second highest category obtaining 0.232 weight. It can be seen that the difference between B-1 and B-2 categories is 0.013, which is not substantial and therefore implies somewhat equal importance of both categories. This is because the effective policy making and easy regulatory framework are paramount to attract RE investment while better market competitiveness of renewables provides them an edge on traditional technologies.

Technical (B-4) category also grasped considerable weight (0.215) and came at third place. These three barrier categories, i.e. B-1, B-2, and B-4, constituted 69.2% of total weight. Social (B-5) and Institutional (B-3) categories were ranked fourth and fifth with respective weights of 0.164 and 0.144.

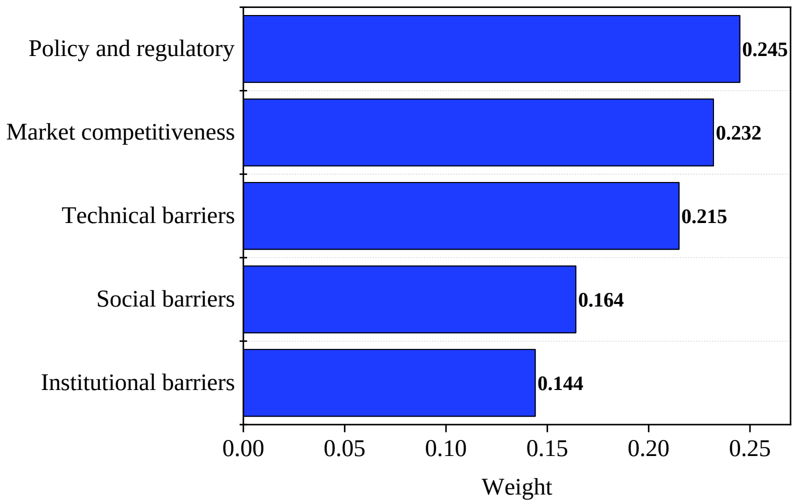

Fig. 6. The ranking of major barriers

5.2. Sub-barriers

Political and regulatory: Fig. 7 presents the results of political and regulatory sub-barriers. The ranking of sub-barriers within Political and Regulatory (B-1) category is as follows: B-13>B-12>B-14>B-11>B-15.

Political instability (B-13) has been reported as the most important political and regulatory sub-barrier by obtaining 0.243 weight. The ranking is justifiable because Pakistan has a long history of political instability, which highly influences every sector, including RE. Political instability can hinder renewable development in a number of ways such as, investors are unwilling to invest in a country whose government is likely to be toppled; people cannot afford to support innovation when they are worried about persistent political upheavals; many people opt to emigrate from the country due to the unstable political environment.

The second highest sub-barrier within this category is the absence of coherent RE policy (B-12) with 0.217 weight. It is also pointed out by various studies that the lack of clarity on medium and long-term policy for renewable capacity expansion, infrastructure, and grid build-out, and environmental goals tend to discourage investors (Selianko and Lenschow, 2015).

Corruption and nepotism (B-14) received 0.209 weight and came third in the row. This issue has also been widely reported in the literature. Javaid (2010) reported that corruption and nepotism are widespread in Pakistan while no structure, no office, and no tier of the public sector is immune from these curses. Farooq et al. (2013) in their study of investigating the impacts of corruption on the economic growth, confirmed that corruption is the major impediment to economic growth in Pakistan. Inadequate regulatory framework (B-11) and lengthy regulatory approval and permit procedures (B-15) obtained 0.168 and 0.163 weights and got fourth and fifth positions, respectively.

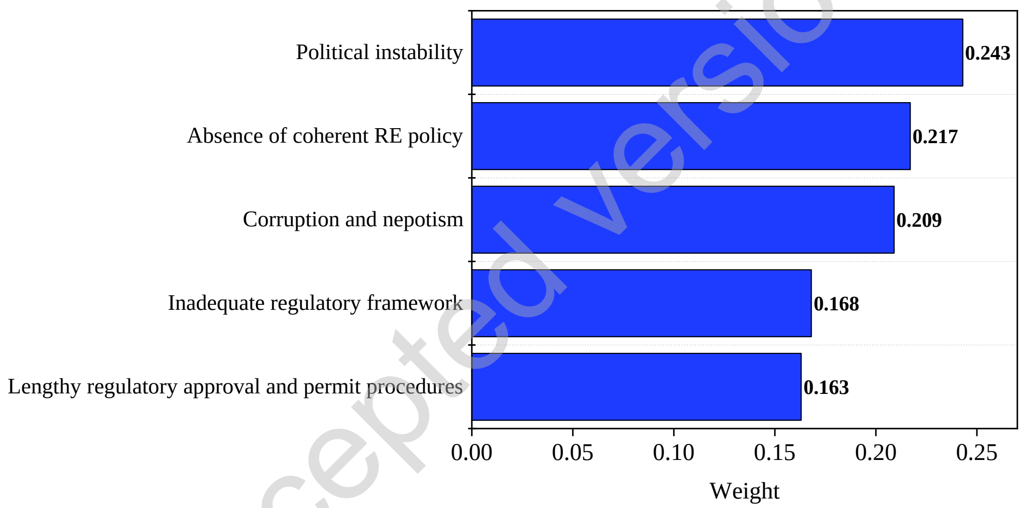

Fig. 7. The ranking of political and regulatory sub-barriers

Market competitiveness: Under the Market Competitiveness (B-2) category, the ranking of sub-barriers is B21>B-23>B-25>B-22>B-24, as shown in Fig. 8. High upfront cost topped the list within this category by receiving 0.252. The result implies that renewables are more capital intensive than conventional energy sources. It is a fact the cost of renewable energies has decreased over time. However, the cost in developing and emerging economies tends to be higher. This encourages the use of fossil fuels and in turn, reduces renewable energies market competition.

The second highest sub-barrier in this category is fossil fuels subsidies (B-23). For many years, the government of Pakistan has been providing high levels of subsidies on the production and consumption of fossil fuels. These subsidies create disadvantages for renewable energies and act as a barrier to the development of RE technologies. Three main impacts of fossil fuels subsidies on renewable technologies have been identified. First, subsidies reduced the cost of conventional electricity and therefore impair cost competitiveness of renewables. Second, subsidies create an incumbent advantage in increasing fossil fuels' position in the electricity system. Finally, subsidies create favorable conditions under which investors prefer fossil fuel technologies over renewable alternatives (Bárány and Grigonytė, 2015).

Lack of access to credit funds (B-25) received 0.196 weight and came on the third position. RE technologies are at early stages in Pakistan, and therefore, financial institutions are less confident to fund renewable projects. Lack of subsidies on renewables (B-22) got the fourth position by obtaining 0.179 weight.

Last in the list is unfavorable electricity prices (B-24) which got 0.165 weight. Lack of subsidies deprives renewables in favor of continued reliance on conventional electricity. Moreover, the consumer price of conventional electricity in Pakistan is below the supply cost of electricity. These factors altogether create hurdles for alternative technologies to effectively compete already matured conventional electricity sources.

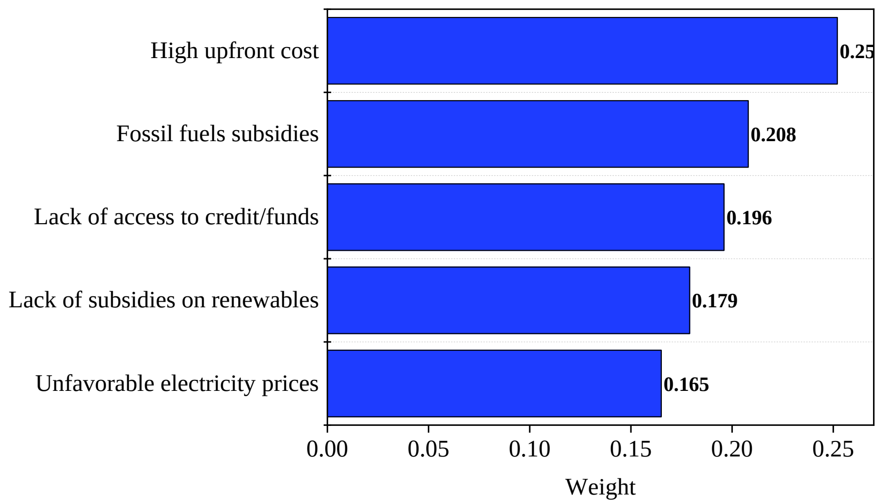

Fig. 8. The ranking of market competitiveness sub-barriers

Institutional: The ranking of sub-barriers within institutional barrier (B-3) category is given in Fig. 9, which shows that B-31>B-32 by 0.07. Lack of institutional coordination received 0.535 weight and was ranked first between two sub-barriers identified under institutional barrier category. The weight of lack of institutional capacity was calculated to be 0.465, and this sub-barrier was subsequently ranked second within major barrier category. Pakistan has a lack of proper and effective institutional framework, which is due to weak coordination among different institutions responsible for the development and promotion of RE technologies and both the urban and rural areas.

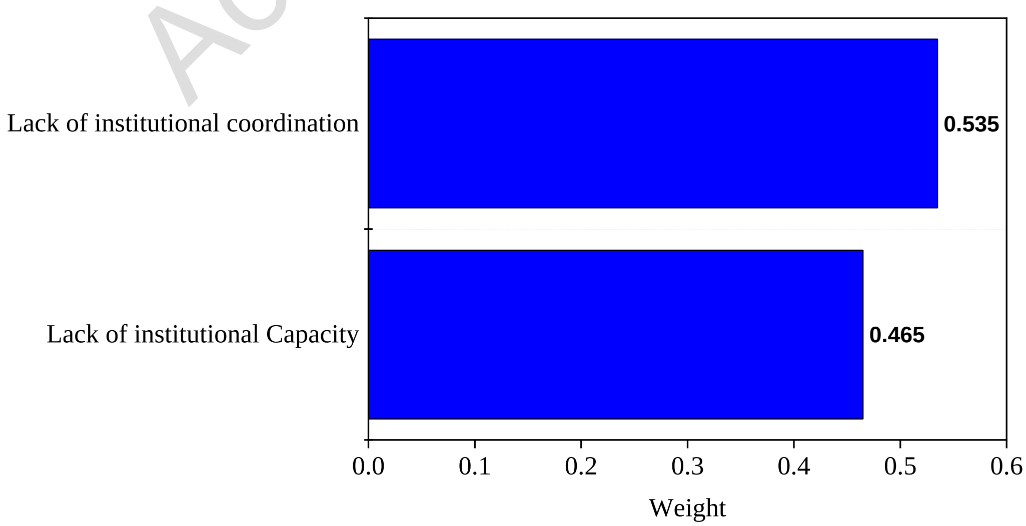

Fig. 9. The ranking of institutional sub-barriers

Technical: From the results presented in Fig. 10, the ranking of sub-barriers within Technical barrier (B-4) category is B-44>B-41>B-43>B-46>B-42>B-45. Lack of infrastructure holds the first position within this category by obtaining 0.211 weight, whereas inadequate technology comes second by receiving 0.205 weight. The difference between the weights of these two sub-barriers remained as low as 0.006, which shows their almost equal importance in restricting RE adoption in Pakistan. Almost 60% of the population in Pakistan reside in rural areas and are disconnected from the national grid due to the absence of grid mechanism and transmission lines. Moreover, the existing transmission and distribution infrastructure is unable to capture electricity from RE installations and transport it to consumers without evading heavy transmission losses. Therefore, without adequate infrastructure in place, the investors lose confidence in renewable technologies and hesitate to invest in this sector. Similarly, there is an influx of sub-standard technologies into the Pakistani market due to the absence of proper standard-checking bodies to check imported technologies. This results in customers not trusting renewables.

Third and fourth sub-barriers in the list are lack of local manufacturing units and lack of operation and maintenance (O&M) facilities which obtained 0.156 and 0.148 weights respectively. Lack of locally manufactured state-of-the-art equipment is another key factor. Lack of local manufacturing facilities not only result in increased cost of equipment due to being imported but also slow down domestic industrial development.

Lack of skilled manpower received 0.174 weight and is on number five in the list. Though on number five, this sub-barrier yet plays a vital role in shrinking renewables widespread. Lack or absence of technicians well-versed in troubleshooting, maintenance, and repair affect customer's reliability. Last in this category is lack of research and development (R&D) facilities which obtained 0.133.

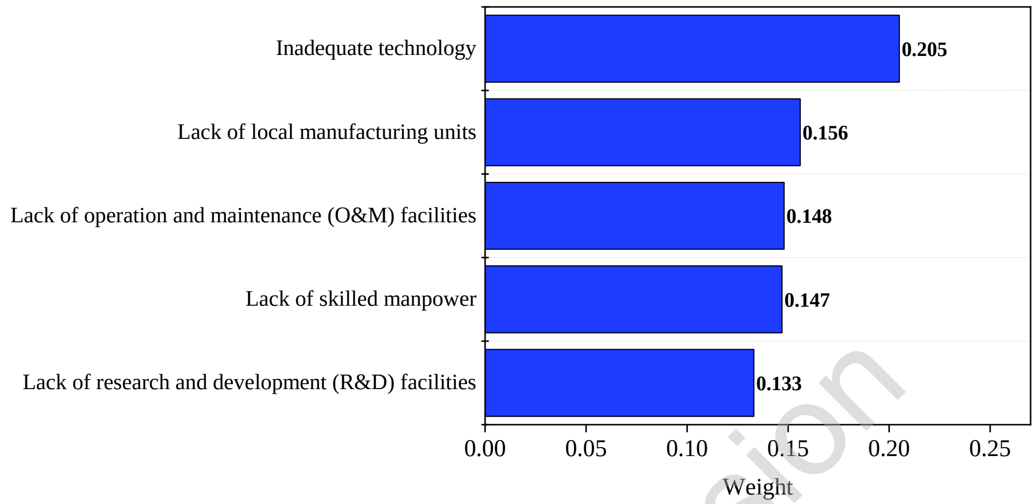

Fig. 10. The ranking of technical sub-barriers

Social: Fig. 11 shows the ranking of sub-barriers within Social barrier (B-5) category, which is as follows: B-51>B-52>B-53. Lack of public awareness has been widely reported as a major barrier, particularly in developing countries. Similarly, the lack of public awareness poses a serious hurdle in the adoption of renewable theologies in Pakistan. It is because most of the people in Pakistan live in rural areas, and thus their level of education is very low to understand the benefits of renewable energies. This is reflected in the results which show that the lack of public awareness is the first ranking social barrier obtaining 0.393 score.

Lack of customers paying capacity ranks second with 0.320 weight. Most Pakistanis view renewables as new technologies affordable by the wealthy in society. Thus, most of the low-income earners depend on conventional electricity, which is cheaper. Lack of social acceptance ranks third obtaining 0.286 weight. The significance of this sub-barrier has been increasing worldwide as more of the large scale renewable projects have been implemented. In Pakistan, however, social acceptance is less significant because the number of large scales of renewable projects is very low.

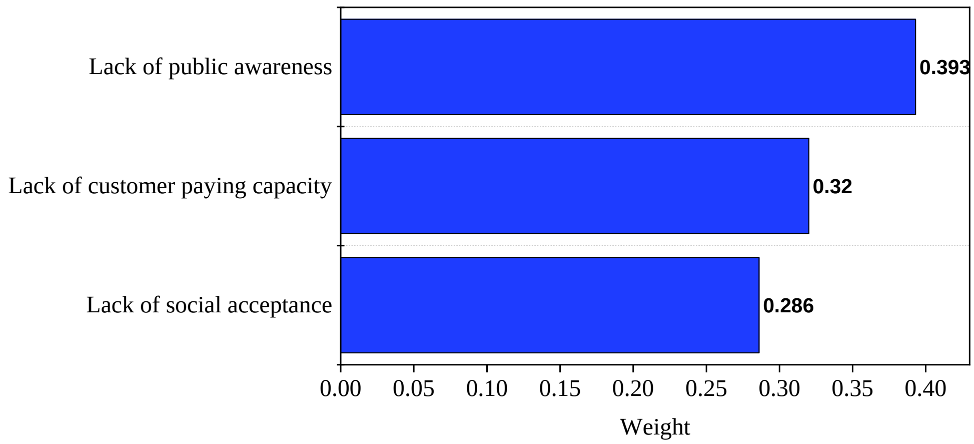

Fig. 11. The ranking of social sub-barriers

5.3. Overall ranking

The final weights of sub-barriers were obtained by multiplying each sub-barrier's weight by the weight of its respective category. Table 10 presents the sub-barriers' final weights.

Table 10. The final weights of sub-barriers

Major barriers	Major barriers weight	Sub-barriers Code	CR	Ratio weight	Final weight
	0.245	B-11	0.0104	0.168	0.0412
Political and regulatory		B-12		0.217	0.0532
		B-13		0.243	0.0595
		B-14		0.209	0.0512
		B-15		0.163	0.0399
	0.232	B-21	0.0107	0.252	0.0585
Market competitiveness		B-22		0.179	0.0415
		B-23		0.208	0.0483
		B-24		0.165	0.0383
		B-25		0.196	0.0455
Institutional barriers	0.144	B-31	0.0000	0.535	0.0154
		B-32		0.465	0.0134
Technical barriers	0.215	B-41	0.0161	0.205	0.0441
		B-42		0.147	0.0316
		B-43		0.156	0.0335
		B-44		0.211	0.0454
		B-45		0.133	0.0286
		B-46		0.148	0.0318
Social barriers	0.164	B-51	0.0004	0.393	0.0215
		B-52		0.286	0.0156
		B-53		0.32	0.0175

Fig. 12 shows the overall ranking of sub-barriers, which is based on final weights obtained. The ranking of sub-barrier is: B-13>B-21>B-12>B-14>B-23>B-25>B-44>B-41>B-22>B-11>B-15>B-24>B-43>B-46>B-42>B-45>B-51>B-53>B-52>B-31>B-32. Political instability reported to receive highest weight (5.95%) among all sub-barriers followed by high upfront cost (5.85%). Third and fourth important sub-barriers are the absence of coherent RE policy and corruption/nepotism with respective weights of (5.23%) and (5.12%). The last four sub-barriers in the row with slight weight differences are lack of customer paying capacity (1.75%), lack of social acceptance (1.56%), lack of institutional coordination (1.54%), and lack of institutional capacity (1.43%).

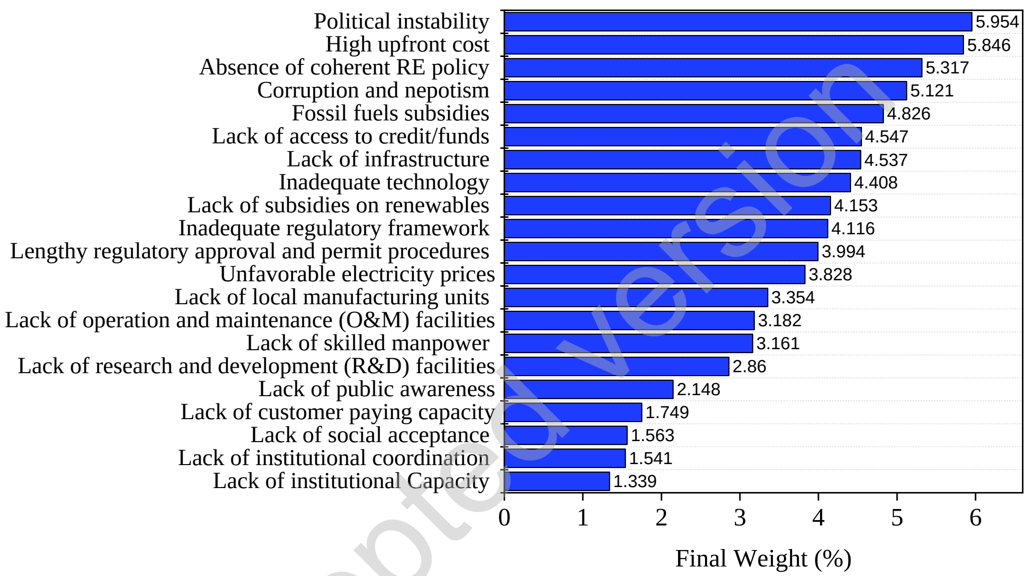

Fig. 12. The final ranking of sub-barriers

6. Conclusion

This study has been conducted to identify and prioritize/rank barriers based on the degree to which they hinder RE adoption in Pakistan. Initially, numerous barriers were identified from the literature, which were then filtered/refined with the help of experts in the field using the Modified Delphi method. Twenty-one barriers were finalized under five major categories, such as political and regulatory, market competitiveness, institutional, technical, and social. Fuzzy AHP was employed to obtain weights and rankings of each barrier and sub-barrier. Results revealed the political and regulatory barrier as the most crucial barrier category followed respectively by market competitiveness, technical, social, and institutional. Ranking of sub-barriers discovered political instability as the main sub-barrier to the adoption of RE development and deployment in Pakistan.

Based on the findings, the study suggests the establishment of an effective institutional and governance system that promotes RE by easing the permitting procedures and developing enabling policies. The holistic and coherent policies must define RE targets, technology mandates, and quotas. The financial incentives provided to both energy generators and end-users must be well inscribed in the policy. Also, the government must create a level playing field for RE by providing capital subsidies on RE equipment. Access to attractive loans for all levels of stakeholders must be facilitated. Certification and standards of RE technologies shall enable phasing out substandard and unreliable equipment from the market. Raising awareness regarding the benefits of RE is duly essential. Further, policy steps to counter RE barriers must evolve to cope with any new barriers.

Reference

Adamo, J.M., 1980. Fuzzy decision trees. Fuzzy sets Syst. 4, 207–219.

Bárány, A., Grigonytė, D., 2015. Measuring fossil fuel subsidies. ECFIN Econ. Br. 40, 1–13.

Bique, A.O., Zondervan, E., 2018. An outlook towards hydrogen supply chain networks in 2050—Design of novel fuel infrastructures in Germany. Chem. Eng. Res. Des. 134, 90–103.

Bloomberg NEF, 2018. New Energy Outlook 2018, [WWW Document]. URL https://about.bnef.com/new-energy-outlook/ (accessed 9.2.19).

Bouzon, M., Govindan, K., Rodriguez, C.M.T., Campos, L.M.S., 2016. Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. Resour. Conserv. Recycl. 108, 182–197.

Calabrese, A., Costa, R., Levialdi, N., Menichini, T., 2019. Integrating sustainability into strategic decision-making: A fuzzy AHP method for the selection of relevant sustainability issues. Technol. Forecast. Soc. Change 139, 155–168.

Chang, C.-W., Wu, C.-R., Chen, H.-C., 2008. Using expert technology to select unstable slicing machine to control wafer slicing quality via fuzzy AHP. Expert Syst. Appl. 34, 2210–2220.

Chang, D.-Y., 1996. Applications of the extent analysis method on fuzzy AHP. Eur. J. Oper. Res. 95, 649–655.

Choudhary, D., Shankar, R., 2012. An STEEP-fuzzy AHP-TOPSIS framework for evaluation

and selection of thermal power plant location: A case study from India. Energy 42, 510–521.
Farooq, A., Shahbaz, M., Arouri, M., Teulon, F., 2013. Does corruption impede economic growth in Pakistan? Econ. Model. 35, 622–633.
Farooq, M.K., Kumar, S., 2013. An assessment of RE potential for electricity generation in Pakistan. Renew. Sustain. Energy Rev. 20, 240–254.
Farooqui, S.Z., 2014. Prospects of renewables penetration in the energy mix of Pakistan. Renew. Sustain. Energy Rev. 29, 693–700.
Fattahi, R., Khalilzadeh, M., 2018. Risk evaluation using a novel hybrid method based on FMEA, extended MULTIMOORA, and AHP methods under fuzzy environment. Saf. Sci. 102, 290–300.
Framework, P., 1994. Package of Incentives for Private Sector Power Generation Projects in Pakistan. Gov. Pakistan.
Gabriele, A., 2004. Policy alternatives in reforming energy utilities in developing countries. Energy Policy 32, 1319–1337.
Ghimire, L.P., Kim, Y., 2018. An analysis on barriers to renewable energy development in the context of Nepal using AHP. Renew. energy 129, 446–456.
Gielen, D., Boshell, F., Saygin, D., Bazilian, M.D., Wagner, N., Gorini, R., 2019. The role of renewable energy in the global energy transformation. Energy Strateg. Rev. 24, 38–50.
Goyal, R.K., Kaushal, S., Sangaiah, A.K., 2018. The utility based non-linear fuzzy AHP optimization model for network selection in heterogeneous wireless networks. Appl. Soft Comput. 67, 800–811.
Hassan, M., Afridi, M.K., Khan, M.I., 2017. An overview of alternative and renewable energy governance, barriers, and opportunities in Pakistan. Energy Environ. 0958305X17743036.
Heo, E., Kim, J., Boo, K.-J., 2010. Analysis of the assessment factors for renewable energy dissemination program evaluation using fuzzy AHP. Renew. Sustain. Energy Rev. 14, 2214–2220.
Ho, W., 2008. Integrated analytic hierarchy process and its applications–A literature review. Eur. J. Oper. Res. 186, 211–228.
Hsu, P.-F., Wu, C.-R., Li, Y.-T., 2008. Selection of infectious medical waste disposal firms by using the analytic hierarchy process and sensitivity analysis. Waste Manag. 28, 1386–1394.
Hussain, A., Rahman, M., Memon, J.A., 2016. Forecasting electricity consumption in Pakistan: The way forward. Energy Policy 90, 73–80.
Jacobson, M.Z., Delucchi, M.A., Bauer, Z.A.F., Goodman, S.C., Chapman, W.E., Cameron, M.A., Bozonnat, C., Chobadi, L., Clonts, H.A., Enevoldsen, P., Erwin, J.R., Fobi, S.N., Goldstrom, O.K., Hennessy, E.M., Liu, J., Lo, J., Meyer, C.B., Morris, S.B., Moy, K.R., O'Neill, P.L., Petkov, I., Redfern, S., Schucker, R., Sontag, M.A., Wang, J., Weiner, E., Yachanin, A.S., 2017. 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World. Joule. https://doi.org/10.1016/j.joule.2017.07.005
Jain, V., Sangaiah, A.K., Sakhuja, S., Thoduka, N., Aggarwal, R., 2018. Supplier selection using fuzzy AHP and TOPSIS: a case study in the Indian automotive industry. Neural Comput. Appl. 29, 555–564.
Javaid, U., 2010. Corruption and its deep impact on good governance in Pakistan. Pak. Econ. Soc. Rev. 123–134.
Kamran, M., 2018. Current status and future success of renewable energy in Pakistan. Renew.

Sustain. Energy Rev. 82, 609–617.
Kessides, I.N., 2013. Chaos in power: Pakistan's electricity crisis. Energy Policy 55, 271–285. https://doi.org/10.1016/j.enpol.2012.12.005
Khan, H.A., Pervaiz, S., 2013. Technological review on solar PV in Pakistan: Scope, practices and recommendations for optimized system design. Renew. Sustain. Energy Rev. 23, 147–154.
Khan11, A.N., Begum, T., Sher, M., 2012. Energy crisis in Pakistan: causes and consequences.
Khattak, N., Riaz Ul Hassnain, S., Shah, S.W., Mutlib, A., 2006. Identification and removal of barriers for renewable energy technologies in Pakistan, in: Proceedings - 2nd International Conference on Emerging Technologies 2006, ICET 2006. pp. 397–402. https://doi.org/10.1109/ICET.2006.335984
Lee, M., Pham, H., Zhang, X., 1999. A methodology for priority setting with application to software development process. Eur. J. Oper. Res. 118, 375–389.
Lin, B., Raza, M.Y., 2019. Analysis of energy related CO2 emissions in Pakistan. J. Clean. Prod.
Lummus*, R.R., Vokurka, R.J., Duclos, L.K., 2005. Delphi study on supply chain flexibility. Int. J. Prod. Res. 43, 2687–2708.
Luthra, S., Kumar, S., Garg, D., Haleem, A., 2015. Barriers to renewable/sustainable energy technologies adoption: Indian perspective. Renew. Sustain. energy Rev. 41, 762–776.
Malik, A., 2007. Effectiveness of regulatory structure in the power sector of Pakistan. Pakistan Institute of Development Economics.
McCollum, D.L., Zhou, W., Bertram, C., De Boer, H.-S., Bosetti, V., Busch, S., Després, J., Drouet, L., Emmerling, J., Fay, M., 2018. Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. Nat. Energy 3, 589.
Mirjat, N.H., Uqaili, M.A., Harijan, K., Valasai, G. Das, Shaikh, F., Waris, M., 2017. A review of energy and power planning and policies of Pakistan. Renew. Sustain. Energy Rev. 79, 110–127.
Mirjat, N.H., Uqaili, M.A., Harijan, K., Walasai, G. Das, Mondal, M.A.H., Sahin, H., 2018. Long-term electricity demand forecast and supply side scenarios for Pakistan (2015–2050): A LEAP model application for policy analysis. Energy 165, 512–526.
Mirza, U.K., Ahmad, N., Harijan, K., Majeed, T., 2009. Identifying and addressing barriers to renewable energy development in Pakistan. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2007.11.006
Mirza, U.K., Ahmad, N., Majeed, T., Harijan, K., 2007. Wind energy development in Pakistan. Renew. Sustain. Energy Rev. 11, 2179–2190.
Moktadir, A., Rahman, T., Jabbour, C.J.C., Ali, S.M., Kabir, G., 2018. Prioritization of drivers of corporate social responsibility in the footwear industry in an emerging economy: A fuzzy AHP approach. J. Clean. Prod. 201, 369–381.
Murry Jr, J.W., Hammons, J.O., 1995. Delphi: A versatile methodology for conducting qualitative research. Rev. High. Educ. 18, 423–436.
Nepal, B., Yadav, O.P., Murat, A., 2010. A fuzzy-AHP approach to prioritization of CS attributes in target planning for automotive product development. Expert Syst. Appl. 37, 6775–6786.
NEPRA, 2017. State of Industry Report 2017.
NEPRA, 2010. National Electric Power Regulatory Authority, Annual Report 2010-2011.
Okoli, C., Pawlowski, S.D., 2004. The Delphi method as a research tool: an example, design considerations and applications. Inf. Manag. 42, 15–29.

Patil, S.K., Kant, R., 2014. A fuzzy AHP-TOPSIS framework for ranking the solutions of Knowledge Management adoption in Supply Chain to overcome its barriers. Expert Syst. Appl. 41, 679–693.
Qudrat-Ullah, H., 2005. MDESRAP: a model for understanding the dynamics of electricity supply, resources and pollution. Int. J. Glob. Energy Issues 23, 1–14.
Rafique, M.M., Rehman, S., 2017. National energy scenario of Pakistan–Current status, future alternatives, and institutional infrastructure: An overview. Renew. Sustain. Energy Rev. 69, 156–167.
Robbins, R.C., Mcmanus, R.P., Mitchell, R.S., Latter, D.R., Moon, M.R., Olinger, G.N., Miller, D.C., 1993. Management of patients with intramural hematoma of the thoracic aorta. Circulation 88, II1-10.
Saaty, T.L., 1988. What is the analytic hierarchy process?, in: Mathematical Models for Decision Support. Springer, pp. 109–121.
Selianko, I., Lenschow, A., 2015. Energy policy coherence from an intra-institutional perspective: Energy security and environmental policy coordination within the European Commission. Eur. Integr. online Pap. 19.
Shah, A.A., Qureshi, S.M., Bhutto, A., Shah, A., 2011. Sustainable development through renewable energy—The fundamental policy dilemmas of Pakistan. Renew. Sustain. Energy Rev. 15, 861–865.
Shah, S.A.A., Valasai, G. Das, Memon, A.A., Laghari, A.N., Jalbani, N.B., Strait, J.L., 2018. Techno-economic analysis of solar PV electricity supply to rural areas of Balochistan, Pakistan. Energies 11. https://doi.org/10.3390/en11071777
Shaikh, F., Ji, Q., Fan, Y., 2015. The diagnosis of an electricity crisis and alternative energy development in Pakistan. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2015.08.009
Shakeel, S.R., Takala, J., Shakeel, W., 2016. Renewable energy sources in power generation in Pakistan. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2016.06.016
Sheikh, M.A., 2010. Energy and renewable energy scenario of Pakistan. Renew. Sustain. Energy Rev. 14, 354–363.
Singh, A., Prasher, A., 2019. Measuring healthcare service quality from patients' perspective: using Fuzzy AHP application. Total Qual. Manag. Bus. Excell. 30, 284–300.
Sun, C.-C., 2010. A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. Expert Syst. Appl. 37, 7745–7754.
Sung, W.C., 2001. Application of Delphi method, a qualitative and quantitative analysis, to the healthcare management. J. Healthc. Manag. 2, 11–19.
Tooranloo, H.S., Azadi, M.H., Sayyahpoor, A., 2017. Analyzing factors affecting implementation success of sustainable human resource management (SHRM) using a hybrid approach of FAHP and Type-2 fuzzy DEMATEL. J. Clean. Prod. 162, 1252–1265.
Vishwakarma, V., Garg, C.P., Barua, M.K., 2019. Modelling the barriers of Indian pharmaceutical supply chain using fuzzy AHP. Int. J. Oper. Res. 34, 240–268.
Wang, B., Song, J., Ren, J., Li, K., Duan, H., Wang, X., 2019. Selecting sustainable energy conversion technologies for agricultural residues: A fuzzy AHP-VIKOR based prioritization from life cycle perspective. Resour. Conserv. Recycl. 142, 78–87.
Wu, Y., Li, L., Song, Z., Lin, X., 2019. Risk assessment on offshore photovoltaic power generation projects in China based on a fuzzy analysis framework. J. Clean. Prod. 215, 46–62.

Yazdanie, M., Economics, E., Rutherford, P.D.T., 2010. Renewable energy in Pakistan: policy strengths, challenges & the path forward. ETH Zurich 112–119.

Yousuf, I., Ghumman, A.R., Hashmi, H.N., Kamal, M.A., 2014. Carbon emissions from power sector in Pakistan and opportunities to mitigate those. Renew. Sustain. Energy Rev. 34, 71–77.