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Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Abbasi, Sikander Ali/Harijan, Khanji et. al. (2021). Is nuclear power generation a viable alternative to the energy needs of Pakistan? : SWOT-RII analysis. In: International Journal of Energy Economics and Policy 11 (4), S. 529 - 536. https://www.econjournals.com/index.php/ijeep/article/download/11122/5952. doi:10.32479/ijeep.11122.

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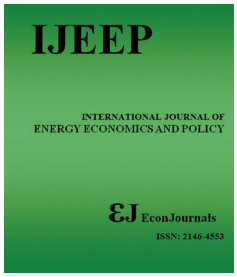

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2021, 11(4), 529-536.

Is Nuclear Power Generation a Viable Alternative to the Energy Needs of Pakistan? SWOT-RII Analysis

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Received: 25 January 2021 **Accepted:** 10 May 2021 **DOI:** https://doi.org/10.32479/ijeep.11122

ABSTRACT

Pakistan has faced a severe energy crisis for the last two decades. With the considerable power generation expansion, the country still faces power outages with an unsustainable energy mix. Successive energy policies emphasized thermal power deployment which has proved to be a part of the problem. Therefore, the present study has attempted to evaluate and investigate the prospects of nuclear power as a viable alternative in terms of energy security, reliability, and environmental sustainability with the SWOT tool. To further quantify the main drivers and barriers of nuclear energy, a Relative Importance Index (RII) analysis has been done. The results reveal that Pakistan has decades of experience running nuclear power plants satisfactorily. The regulatory framework for nuclear power generation is adequate to expand nuclear power generation. The opportunities are enormous to meet Sustainable Development Goal (SDG), as nuclear is a carbon-free source of energy. The main barriers are global suspicion of nuclear proliferation and less social acceptance.

Keywords: SWOT, Delphi, RII Analysis, Nuclear Power Generation
JEL Classifications: P4,Q4

1. INTRODUCTION

Pakistan has faced a severe electricity crisis due to a persistent gap between the demand and supply of electricity. This resulted in the loss of GDP, closure of industries, unemployment, and stress on the social fabric of society. The power crisis did not emerge suddenly. It is the outcome of flawed energy policies, weak physical and institutional infrastructure, poor governance, and lack of political will. The first power policy in the country was announced in 1994 which stressed the need to add imported fossil fuel-based thermal power generation to immediately bridge the widening gap of demand and supply. This resulted in an inefficient energy mix which compromised energy security, affordability, and environmental sustainability. Later on, various attempts were made to diversify the energy mix to enhance energy security. The global transition to carbon-free electricity has little impact on Pakistan as the country continues to rely on imported fuel. The share-wise electricity generation in Pakistan is shown in Figure 1.

To further diversify the energy mix, subsequent power policies were announced, however, the share of carbon-free electricity remained low. Pakistan still struggles to enhance renewable energy in its total energy mix as such Alternative and Renewable Energy (Renewable Energy Policy, 2019) policy was announced with the target to enhance the share of renewable to 30% by the year 2030. With such an ambitious target of renewables, nuclear power

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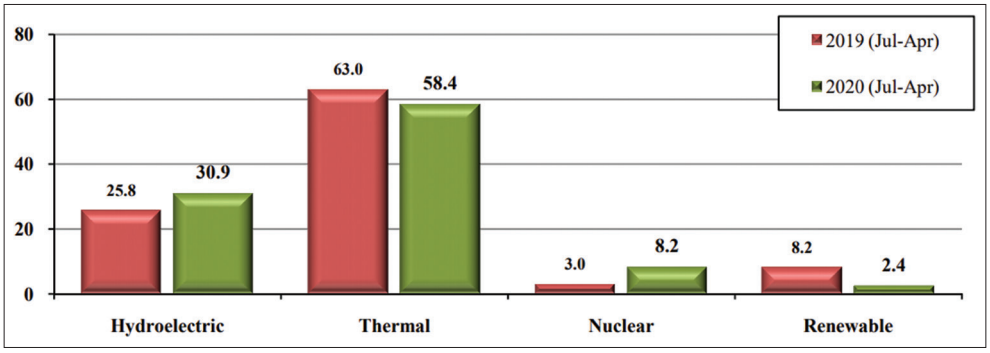
Figure 1: The share of electricity by source (Ministry of Finance, 2019)



generation has also increased from 149 MW in 1972 to 1430 MW in 2020. The first nuclear power plant was commissioned in 1972 with the cooperation of Canada in the coastal city of Karachi. After a reasonable gap of 28 years, the second nuclear power plant was made operational with a capacity of 300 MW in 2000 at Chashma, Punjab province of Pakistan. Since then, Pakistan has shown considerable interest in adding nuclear power generation to its total energy mix. Presently nuclear power contributes 6.2% of electricity in the total energy mix of Pakistan. The total cumulative generating capacity of nuclear energy in the country is 1430 MW. Five nuclear power plants are operational whereas two reactors are under construction. The status of nuclear power plants in Pakistan is shown in Table 1.

Pakistan Atomic Energy Commission (PAEC) is responsible for the development of nuclear power in the country. The licenses to nuclear installations including nuclear power plants are granted by the Pakistan Nuclear Regulatory Authority (PNRA). The PNRA prepares and executes effective regulations to ensure the safe operation of all nuclear installations including nuclear power plants. With 1430 MW electricity generation capacity, the country is set to add 2028 MW of electricity from nuclear power in 2020. With the depleting reserves of natural gas and unstable prices of imported oil, nuclear power generation has attracted the attention of policymakers to enhance the share of nuclear energy in the total energy mix. Pakistan as a developing country has therefore intricate choices to diversify its power generation capacity. Therefore, nuclear power generation appears to be an appealing option as an alternative energy source to enhance energy security, reliability, and environmental sustainability and that is the motivation for carrying out this study. The structure of the paper is such that section 2 presents the literature review. Section 3 offers a methodology. Section 4 discusses the results. The conclusion is given in section 4.

2. LITERATURE REVIEW

Many studies have been conducted to evaluate the main drivers and barriers to power generation sources globally. Many tools in literature are found which are used for the evaluation of strong and weak indicators of power generation. SWOT is one of the very useful tools to perform such a task. It 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 mending or avoid their weaknesses and to protect against any unknown

Table 1: Status of nuclear power plants in Pakistan

Reactor unit	Type	Net capacity (MW)	Status	Commercial date
CHASNUPP-1	PWR	300	Operational	September 15, 2000
CHASNUPP-2	PWR	300	Operational	May 18, 2011
CHASNUPP-3	PWR	315	Operational	December 01, 2016
CHASNUPP-4	PWR	313	Operational	September 19, 2017
KANUPP - 1	PHWR	90	Operational	December 07, 1972
KANUPP - 2	PWR	1014	Under construction	July 31, 2020
KANUPP - 3	PWR	1014	Under construction	-

Data source: (IAEA, 2020)

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 the ambiguity between strengths and opportunities or between weaknesses and threats. It is important to define external and internal factors before the SWOT analysis is done. Employing SWOT tool alone or in combination with some other tools such as Delphi, AHP Fuzzy, Relative Importance Index (RII) analysis are used for evaluation of prominent positive and negative indicators. Various studies conducted with SWOT alone or with hybrid tools for energy generation technologies are shown in Table 2.

(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.,

Table 2: Various studies undertaken using SWOT and hybrid tools

Author	Analytic tools	Area of study	Country
(Zhao and Yan, 2012)	SWOT	Biomass power generation	China
(Lei et al., 2019)	SWOT	Photovoltaic solar development	Africa
(Shi, 2016)	SWOT	Fossil fuels	ASEAN
(Cayir Ervural et al., 2018)	SWOT, AHP Weighted Fuzzy,	Energy sector	Turkey
(Khalil, 2017)	SWOT	Nuclear power	-
(Fertel et al., 2013)	SWOT	Climate and energy policy	Canada
(Ishola et al., 2019)	SWOT	Nuclear energy	Nigeria
(Wang et al., 2020)	SWOT, Fuzzy, AHP	Renewable energy	Pakistan
(Kamran et al., 2020)	SWOT	Renewable energy	Pakistan
(Kamran et al., 2020)			
(Shakeel et al., 2016)	SWOT	Renewable energy	Pakistan
(Tavana et al., 2012)	SWOT, Delphi	Oil and gas	Capsian sea basin

2019). (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. (Cayir 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 renewable energy. (Wang et al., 2020) conducted SWOT analysis of renewable energy of provinces of Sindh and Baluchistan of Pakistan. 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. They concluded that 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. (Abbasi et al., 2021) used the SWOT-Delphi approach to assess coal power generation as a feasible option for Pakistan. They concluded that coal with renewable energy can meet electricity demand with energy security and environmental sustainability.

All these studies have qualitatively analyzed various energy options for different countries. This study however has evaluated the drivers and barriers of nuclear power for Pakistan with SWOT and relative importance index tool to quantitatively highlight the prominent drivers and barriers for nuclear power generation. The use of the RII analysis tool in power generation is the first such attempt in Pakistan to highlight drivers and barriers to nuclear power generation.

3. METHODOLOGY

The research methodology adopted in this study is shown in Figure 2.

SWOT analysis with Delphi and Relative Importance Index (RII) tool has been applied to evaluate the main drivers (strengths,

Figure 2: Research methodology

opportunities) and barriers (weaknesses, threats) of the nuclear power generation of Pakistan.

3.1. SWOT Analysis

SWOT analysis was conducted to find internal strengths and weaknesses alongside external factors, like opportunities and threats of nuclear power in Pakistan. The following quarries were answered with gathered data, collected from different national and international organizations, newspapers, electronic materials, research journals, and sending Delphi statements in the form of open and closed-ended questionnaires to experts of nuclear energy.

- What is the level of manpower experience?
- Can nuclear power supply baseload power?
- Is nuclear power an environment-friendly source of power generation?
- Is nuclear power generation cost competitive?
- How is the safety culture in Pakistan?
- What are the human health effects of nuclear power generation?
- How nuclear waste is disposed of?

3.2. Delphi Tool

Delphi is a process to decide based on a survey of respondent's judgment in weight based on any undecided topic. In this study, the Delphi method was employed by the following procedure.

Experts from nuclear power generation technology were first identified and asked to participate in the survey. Experts were middle and senior managerial persons who had enough experience in the field of nuclear energy. 60 experts were contacted to respond out of which 45 responded. The response ratio from respondents was 75%. Most respondents were from academia followed by industry, government organizations, and research institutions as shown in Figure 3.

The Delphi statements were developed by the authors and pursued through sequential questionnaires in two rounds.

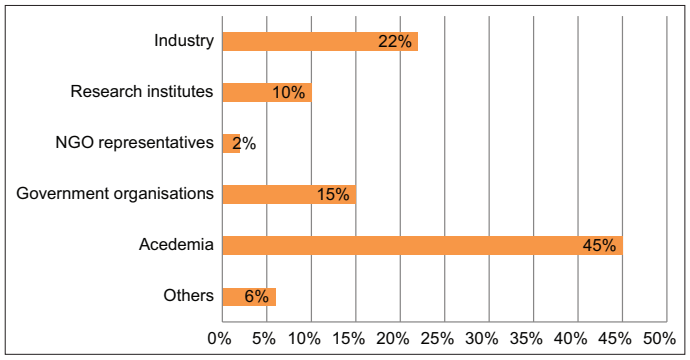
3.3. Relative Importance Index (RII) Analysis

The Relative Importance Index (RII) analysis tool was used to highlight the most important attributes. RII analysis allows identifying most of the important criteria based on participant's replies and it is also an appropriate tool to prioritize indicators rated on the Likert scale. The expert's evaluation was weighted by the Likert Scale. The Likert scale was considered from 1 to 5 points. Each point's remark was documented and 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 is

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

Figure 3: Distribution of the Delphi survey participants according to their significance



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.

Participants were asked to provide their judgment on strengths, weaknesses, opportunities, and threats of nuclear power generation.

The range of participant's opinions is shown in Table 3.

As shown in Figure 4 and 5, the investigation of drivers and barriers of nuclear power generation has been made on three themes i.e., energy security, energy reliability, and environmental sustainability. The selection of themes is based on the following considerations. Since Pakistan has been facing power shortages owing to the demand-supply gap, therefore the reliability of power has been compromised to a considerable extent, and on the other hand, the deployment of thermal power generation has increased GHG emissions. Secondly, these themes are prominent in the literature on energy and climate policies and related reports are available with international organizations.

4. RESULTS AND DISCUSSION

4.1. SWOT Analysis

4.1.1. Strengths

4.1.1.1. Decades of experience

Pakistan established its first nuclear power plant KANUP in 1972 in Karachi with a capacity of 137 MW. In 1976, the vendor withdrew its support to provide spare parts and fuel. The PAEC undertook the task to manufacture spare parts and nuclear fuel indigenously. The power plant completed its design life of 30 years in 2002. The life of the plant was extended for another period after refurbishing all the necessary parts of the plant. Now five more nuclear power plants are operational and a few under construction phase. With this background, the country has enough experience to operate and maintain this technology with international safety standards.

4.1.1.2. An inexhaustible source of energy

Nuclear power generation is an inexhaustible source of energy as compared to any conventional power generation. One uranium fuel pellet creates as much energy as one ton of coal, 149 gallons of oil, or 17,000 cubic feet of natural gas (Insititute, 2020). Therefore, nuclear energy is an alternative source of energy with carbon-free

Figure 4: SWOT synthesis

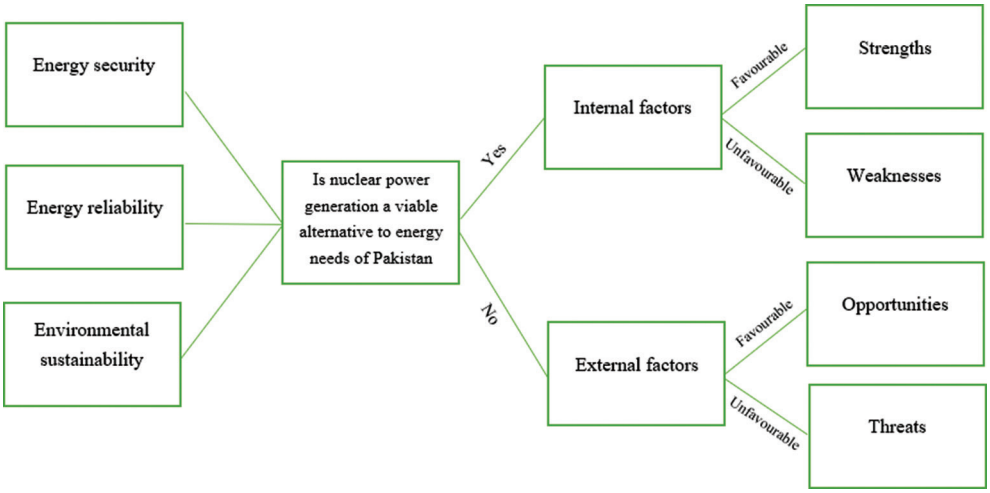


Table 3: Likert scale rating

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

emissions. Pakistan has reasonable reserves of uranium, therefore opting for more nuclear power in its total energy mix will reduce the reliance on imported fuel and enhance the sustainability of the overall power generation portfolio.

4.1.1.3. Baseload power generation

Nuclear power plants are regarded as baseload power sources due to low fuel cost and steady-state power. They run continuously to meet the minimum level of power demand 24/7. Baseload plants are generally large-scale and are key components of an efficient electric grid. Nuclear power plants produce power at a constant rate and are not designed to respond to peak demands or emergencies. Since this power source supplies power to a lower portion of the load duration curve, therefore the sustainability of this power generation is enhanced.

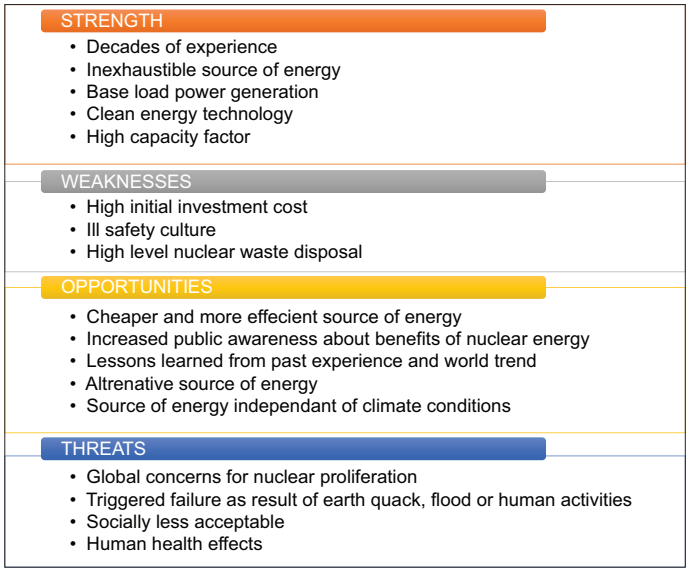
4.1.1.4. Clean energy technology

Nuclear power plants are the main contributor to the reduction in GHG emissions and resulting in global warming. They do not generate polluting emissions such as sulfides, dust, or greenhouse gases. They have around 1.02-1.12% global warming potential. Operating externalities of nuclear electricity are relatively low as the life cycle of nuclear power generates less GHG and particulate matter emissions. Therefore, nuclear energy is an environmentally friendly source of power generation.

4.1.1.5 High-capacity factor

The capacity factor is the ratio between what a generation unit is capable of generating a maximum output versus the unit's actual generation output over a period of time. Nuclear power has the highest capacity factor compared with other generation technologies as shown in Figure 6.

Figure 5: SWOT investigation of nuclear power generation



4.1.2. Weaknesses

4.1.2.1. High initial investment cost

The initial investment cost of nuclear power plants is more than conventional thermal power plants. As per the report published by the World Nuclear Association (WNA), the capital cost of new nuclear power plants is high which is 60% of their Levelized Cost of Electricity (LCOE). For determining the overall capital cost construction period and interest charges are key variables (WNA, 2017).

4.1.2.2. Ill safety culture

There are challenges of safety culture during the commissioning and maintenance of nuclear power plants. Any negligence on the part of human resources can affect safety culture. Developing countries like Pakistan faces a poor safety culture. These challenges are in areas such as maintenance management, human resources management, plant condition assessment, and the business environment. The measures that Pakistan has taken to address safety culture are worth appreciating but it requires continuous monitoring to satisfy the International Atomic Energy Agency (IAEA).

Figure 6: Capacity factors of selected generating technologies (US Energy Information Administration (EIA), 2016)

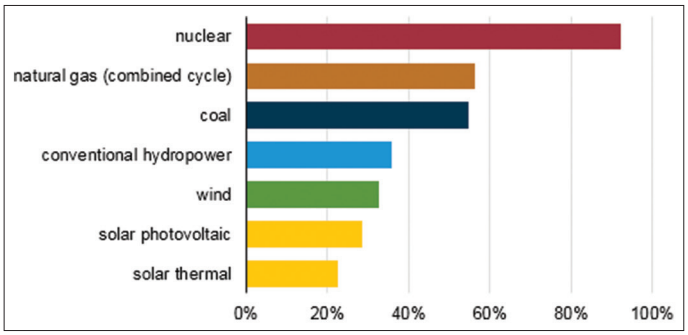
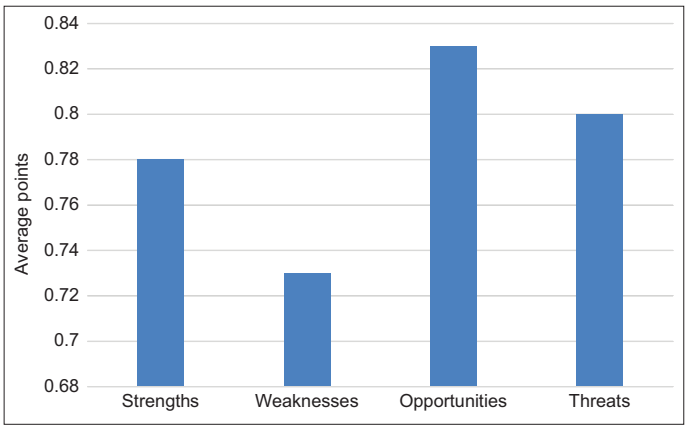


Figure 7: RII average values of strengths, weaknesses, opportunities, threats



4.1.2.3. High-level nuclear waste disposal

With the increasing use of nuclear power generation, there is a growing need for sharing information and knowledge on disposal approaches. Since nuclear waste takes time to decay therefore initially waste is dumped into a water container for quite some time before it is finally disposed to designated repository formation. Continuous monitoring is required to contain radiation within the labeled area. There are chances of groundwater contamination if strict and proper precautionary measures are not taken.

4.1.3. Opportunities

4.1.3.1. Cheaper and more efficient source of energy

The operation cost of nuclear power generation is cheap as compared to thermal power plants as the cost of fuel is less. These plants are highly efficient with 34% efficiency. The power density of nuclear power is also very high as compared to coal and other conventional sources. By enhancing the share of nuclear power, Pakistan will have a better opportunity to balance its diversity in the total energy mix.

4.1.3.2. Increased public awareness about the benefits of nuclear energy

There was a public perception in the world that nuclear power plants are very harmful to humans and the environment. Many pressure groups are active against the commissioning of new nuclear power plants. Germany and Japan are phasing out their nuclear power plants from their countries. However, the public has begun to realize that these plants are efficient and environmentally friendly. Therefore, the public has not shown any resentment over the commissioning of new power plants. These power plants will improve the energy balance and enhance the energy security of Pakistan.

4.1.3.3. Alternative source of energy

With the depleting reserves and increasing prices of fossil fuels, nuclear power generation offers an alternative source of energy around the globe. Nuclear power generation is emission-free. The uranium reserves are abundantly available. Therefore, it is regarded as an alternative source of energy. Pakistan is actively engaged to add the nuclear share to its system. Nuclear power plants of 2200 MW are under construction. Pakistan has planned to add 8800 MW nuclear power to its total energy mix by 2030. This will prove to be an alternative source of energy. It will not only contribute to meet future electricity demand but reduce overall GHG emissions in the country.

4.1.3.4. Source of energy independent of climate conditions

Climate change is a big issue and the power industry is contributing two-third of overall GHG emissions in the environment around the globe. Nuclear power generation is an emission-free source as there are negligible CO_2 emissions. The emissions are comparable with renewable sources like hydropower and wind energy. Nuclear power has 29 tons CO_2 e/GWh emissions as compared to coal 888, natural gas 499, solar 85, hydro 26, wind 26, and lignite 1054 tons CO_2e/GWh (WNA, 2017). From these values, it is evident that nuclear power generation offers a clean source of energy without affecting the climate.

4.1.4. Threats

4.1.4.1. Global concerns for nuclear proliferation

The world gas experienced that many countries who started their nuclear program for energy needs later converted it for non-civilian purposes. This situation raised the apprehensions of the world community about nuclear proliferation. That is why any nuclear energy initiative taken by countries is seen with doubt. In many cases, these countries do not get enough cooperation to enhance their electricity demand through nuclear power.

4.1.4.2. Triggered failure because of earth quack, flood, or human activities

Nuclear accidents including TMI-2 (1979), Chernobyl (1986), and Fukushima Daiichi (2011) have eroded public confidence in the prospects of this industry. These accidents were caused by human error, technical malfunctioning, and earth quack respectively. These accidents crystallized anti-nuclear safety concerns among activists and the public. Such events have been cited as a contributor to the decline of new nuclear power plants around the globe.

4.1.4.3. Socially less acceptable

There is a general perception that nuclear reactors emit radiation that causes damage to human health. The construction of nuclear power plants is seen with suspicion by the public. Therefore, during the commissioning and operational phase, it does not receive any welcoming gesture from the public [Forecasts and Analysis (2008)].

Table 4: RII analysis of nuclear-based power generation

Strengths	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	No: of respondents	R.I. I	R. I. I (AVG)
Decades of experience	2	4	6	24	9	45	0.75	0.78
Inexhaustible source of energy	2	2	5	21	15	45	0.80	
Regulatory framework	2	3	10	20	10	45	0.74	
Established infrastructure	4	6	4	20	15	45	0.74	
Base load power generation	0	1	2	28	14	45	0.84	
Clean energy source	2	2	3	26	12	45	0.79	
Weaknesses	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Total respondents	R.I. I	R. I. I (AVG)
High initial investment cost	0	1	4	20	20	45	0.86	0.73
Ill safety culture	5	7	20	10	3	45	0.59	
High level nuclear waste disposal	2	4	9	20	10	45	0.74	
Opportunities	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Total respondents	R.I. I	R. I. I (AVG)
Cheaper and more efficient source of energy	0	0	5	20	20	45	0.86	0.83
Increased public awareness about benefits of nuclear energy	2	3	10	20	10	45	0.74	
Lessons learned from past experience and world trend	0	0	8	19	18	45	0.84	
Alternative source of energy	0	0	4	21	20	45	0.87	
Source of energy independent of climate conditions	0	2	5	20	18	45	0.84	
Threats	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Total respondents	R.I. I	R. I. I (AVG)
Global concerns for nuclear proliferation	0	4	7	18	16	45	0.80	0.80
Triggered failure as result of earth quack, flood or human activities	0	1	11	19	14	45	0.8	
Socially less acceptable	0	3	6	20	16	45	0.81	
Human health effects	1	2	8	18	16	45	0.80	

4.1.4.4. Human health effects

Nuclear radiations are the major concern of this power generation source. The used parts of the plant and spent fuel contain radiations and they take a long time to decay. Therefore, any breach or mishandling on the part of the handler, can harm humans or contaminate the environment. Generally, nuclear radiation can cause cancer, genetic mutation, and cardiovascular diseases along with psychological effects.

4.2. RII Analysis

The quantitative analysis through RII analysis is shown in Table 4.

The average values of RII analysis were obtained through weightage given by the experts which are shown in Table 4. The average values were calculated for strengths, weaknesses, opportunities, and threats. The opportunities got 0.8 points which are highest than all other parameters as shown in Figure 7. The highest points are attributed to cheap, efficient, and carbon-free source of energy. The second-highest points are 0.8 for threats due to global concerns for nuclear proliferation, health effects, and socially less acceptable. The average value of strengths is 0.78 which is modest owing to decades of experience, better regulatory framework, and inexhaustible source of energy. The weaknesses are quite low with 0.73 points.

5. CONCLUSION

SWOT analyses suggest that the main drivers (strengths and opportunities) are decades of experience, clean source of energy independent of climate conditions. The barriers (weaknesses, threats) are high capital cost, high level of nuclear waste, and socially less acceptable. The quantitative analysis through RII analysis revealed that opportunities have obtained the highest points (0.8) due to a cheaper, efficient, and clean source of energy. The threats have got 0.80 points on account of global concern of nuclear proliferation, risks associated with an accident, safety culture, and human health hazards. Accordingly, nuclear power has modest strengths with the highest opportunities. Therefore, it is fair to conclude that the deployment of a noticeable share of nuclear power in the energy mix of Pakistan, can enhance energy security, reliability, and carbon-free energy for its sustained economic development.

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