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Is Coal Power Generation a Sustainable Solution for Energy Needs of Pakistan: A Delphi-SWOT Paradigm?

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ABSTRACT

This paper aims to apply Delphi and SWOT tools as a reference theme that diagnosis the sustainability of current status and future road map to develop coal based power generation in Pakistan. The SWOT analysis is performed on the themes of energy security, energy efficiency and environmental sustainability. Within this analytical framework, the coal power generation has been discussed in the context of Pakistan's energy scenario through categorical analysis of strengths, weaknesses, opportunities and threats. The paper explores the strength of coal based power production as indigenous coal reserves, internal weaknesses appears to be quality of coal (high moisture content), unavailability of water for power generation at site of coal mines and lack of coherence between coal exploitation and climate change policy. The conversion of coal to gaseous products and liquid fuels offers an opportunity alongside employing advanced technologies of High Efficiency Low Emission (HELE) to cut CO2 emissions. Threats to coal power are its adverse environmental impacts on land, soil and air. Furthermore, to enhance energy security and sustainability, strategic planning based on measures such as cleaner use of coal, promotion of renewables and energy efficiency with flexibility are suggested. Each of these actions require concrete steps from all stakeholders and policy makers to develop coherence between coal exploitation and climate change policy of Pakistan.

Keywords: SWOT Analysis, Delphi, Coal Based Power Generation of Pakistan, Energy Security, Environmental Sustainability.
JEL Classifications: P4, Q4

1. INTRODUCTION

Electricity generation is one of the most indispensable factor to grow economy and improve the living standards of people. It is important for Pakistan to arrange alternative energy choices which will lessen future problems by making electricity available without undue costs, reducing reliance on imported oil and gas, reducing GHG emissions and encouraging sustainable power generation technologies. Pakistan is a growing economy and its electricity consumption is rising at a rate of 11%/year. (Akber et al., 2017). In quest to encounter the growing demand of electricity, Pakistan aims to explore all possible resources to meet energy needs of the country. (Yousuf et al., 2014). After the discovery of coal reserves at Thar, Sindh in southern province of Pakistan, country aims to exploit indigenous coal for electricity generation. Pakistan's total coal reserves are 185 billion tons. Out of total reserves, 175 billion tons are found in Thar region of Pakistan. (WEC, 2013). The province wise coal reserves of Pakistan are shown in Table 1.

The coal resources located in the map at various locations of Pakistan are shown in Figure 1.

Since coal from Thar field contains higher sulphur and moisture content, thus raising the question of its technical and environmental sustainability, therefore these two aspects of coal needs to be examined with care. Pakistan is signatory to international treaties to climate change. As such, country also has framed climate policy to contain CO_2 emissions to produce clean energy. Economic

Figure 1: Coal resources of Pakistan

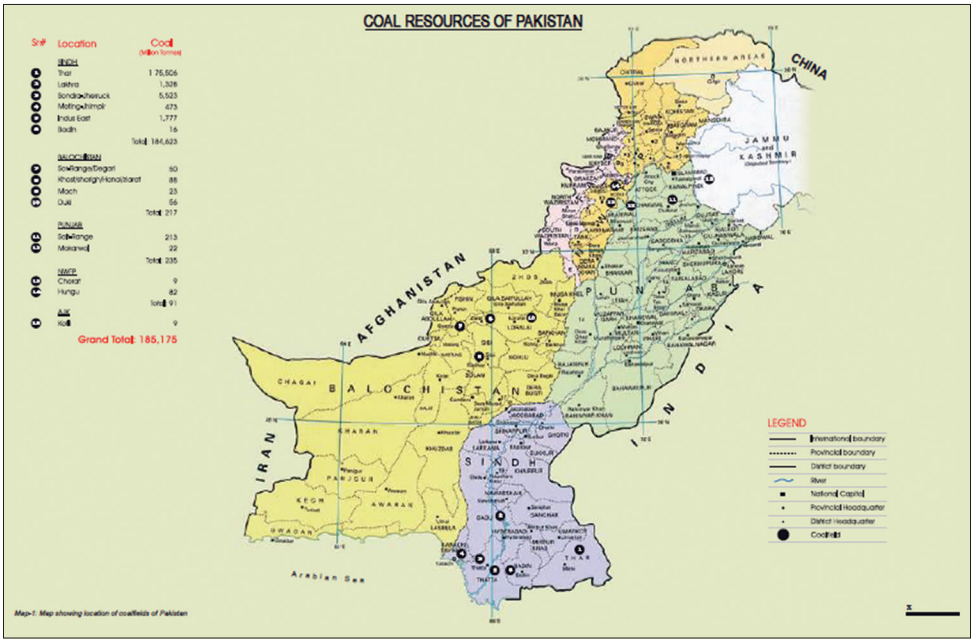


Table 1: Coal reserves of Pakistan (PPIB, 2004)

Province coal fields	Coal resources (million tons)	Heating value (btu/lb)
Sindh		
Thar	175,506	6244-11045219-8612
Lakhra	1328	5219-13,555
Sonda-Jherruk	5523	5219-8612
Meting-Jhampir	473	
Indus East	1777	7,782-8,660
Badin	16	11,415-11,521
Sub-Total	184623	
Balochistan		
Sor-Range/Degari	50	11,245-13,900
Khost-Sharigh-Harnai-Ziarat	88	9,637-15,499
Mach	23	11,110-12,937
Duki	56	10,131-14,357
Sub-Total	217	
Punjab		
Salt-Range	213	9,472-15,801
Makarwal	22	10,688-14,029
Sub-Total	82	
Khyber Pakhtunkhwa		
Hangu	82	10,500-14,149
Cherat	9	9,386-14,217
Sub-Total	91	
Azad Kashmir		
Kotli	9	7,336-12,338
Grand Total	185,175	

improvement, quality of life and social wellbeing of a country can be realized with sustainable means of electricity. At a time when world is undergoing transition from fossil fuels to renewables, many countries with significant coal reserves are reluctant to increase the contribution of renewables to their electricity production mixes (García-Gusano et al., 2018). The coal fired power generation is accompanied with adverse environmental pollution such as air, water, and noise pollution (Wang et al., 2018). The government intends to increase coal share up to 18% by 2025. Various China Pakistan Economic Corridor (CPEC) priority projects based on imported coal are under construction and many are in planning phase. The projects are listed in Table 2. As a result of such huge penetration of local and imported coal based power generation, GHG emissions are anticipated to increase manifold. Generation methods such as coal fired power plants release the majority of GHGs during operation. Accounting for emissions from all phases of the project (construction, operation, and decommissioning) is called a lifecycle approach. Normalizing the lifecycle emissions with electrical generation allows for a fair comparison of the different generation methods on a per gigawatt-hour basis. The lower the value, the less GHG emissions are emitted. Coal fired power plants have the highest GHG emission intensities on a lifecycle basis. Figure 2 show the comparison of lifecycle GHG emissions of various generation technologies. It is clear from the Figure 2 that lignite and coal have 1069 and 888 Tones CO_2e/GWh life cycle GHG emissions respectively which are quite high compared with other power generation sources.

Companies and practitioners have used LCA as a tool to assess the potential environmental impacts of different processes and they can guide their decisions to improve their eco-efficiency. (Mora et al., 2020)

It is pertinent to mention that global trend is to phase out coal power generation, Pakistan is increasing the share of coal in power generation mix which is in contrast to global trend. However Pakistan's reliance on indigenous resources will enhance its energy security. The current contribution of coal power is 8% in Pakistan's total energy mix. At present, the country is generating 660 MW of electricity from coal. It is estimated to reach 18% of total installed capacity by the year 2025 (Pakistan Economic Forum III, Water Panel Report 2015) once all coal-fired power plants are operational. Pakistan is striving to penetrate power generation technologies capable of replacing furnace oil with renewables and coal while containing the anticipated adverse environmental

impacts. Under CPEC energy projects, power plants of various capacity on coal are given in Table 2.

Pakistan seems committed to exploit local coal and enhance the share of coal power in the long term strategy. From 2033 to 2040, around 23760 MW of coal fired power will be added in energy mix of Pakistan as shown in Table 3. (IGCEP, 2018-2040). With such significant increase in coal power, environmental sustainability need to be investigated carefully.

The choice of themes is selected by two main considerations. These themes are prominent in the literature on energy and climate policies and reports are available with international bodies such as the IEA. Energy and climate policies are closely inter- related with each other. Harmonization of energy and climate policies would allow potential collaborations. By diversifying the energy mix, the energy security is increased which will lead to reduction in emissions. Investments in energy-efficient technologies such as super critical, ultra super critical and Carbon Capture and Storage (CCS) contribute to the objectives of climate policies. The integration of these policies will improve the overall efficiency and environmental sustainability.

1.1. Coal Based Power Generation, Global Perspective

Coal is carbon intensive fossil fuel, and for every tons of coal burned, there are approximately 2.5 tons of carbon emissions. To limit global warming, all unabated coal must be phased out within few decades (IEA). Despite these cautions, global coal demand is set to remain stable for next few years. Decline of coal in US and Europe is offset by immediate growth in India and China. Around 4.5GW of coal-fired capacity is going to be retired in the United States by this year, whereas around 13.7 GW of capacity went offline last year alone. (EIA) The rate of growth is slowing dramatically, as the world is switching to renewables. The pipeline of plants under construction or proposed has shrunk by three fifth since 2015. Retirements are also accelerating and reached a cumulative 227 GW between 2010 and 2018. World total share of coal power in 2017 was 38% (Malischek, 2019). The share of electricity generation from various sources is shown in Figure 3.

Over the past few years, coal has moved to Asia. Some countries have devoted to end coal power generation by 2030. Germany has planned to phase out coal by 2038, while the end of coal generation is doubtful in other countries as coal plays significant role for acquiring cheap energy. Asia witnessed the main growth particularly in China and India. Overall, 3% decline of coal investment has been observed in coal fired power, the lowest level since 2004. Electricity generation by coal increased in China and India significantly, but it fell elsewhere, including in the United States and Europe. With 38% share, coal remains the main source of electricity generation worldwide. Phase out of coal has been

Table 2: CPEC energy projects (CPEC-Energy Priority Projects, 2019)

Project Name	Capacity (MW)
2×660 MW Coal-Fired Power Plants at Port Qasim Karachi	1320
Sahiwal 2×660 MW Coal-Fired Power Plants Punjab	1320
Engro Thar Block-II 2×330 MW Coal-Fired Power Plants	660
TEL 1×330 MW Mine Mouth Lignite Fired Power Plants at Thar Block-II, Sindh	330
ThalNova 1×330 MW Mine Mouth Lignited Fired Power Project at Thar Block-II, Sindh	330
300 MW Imported Coal Based Power Project at Gwadar, Pakistan	300
SSRL Thar Coal Block-I 6.8 mtpa and SEC Mine Mouth Power Plant (2×660 MW) (Shanghai)	1320
CPHGC 1320MW Coal-Fired Power Plants at Hub, Balochistan	1320
Thar Mine Mouth Oracle Power Plant (1320 MW) and Surface Mine	1320
Rahimyar Khan Imported Fuel Power Plant	1320

Table 3: Indicative generation capacity expansion plan (IGCEP2018-44)

Fiscal year	Units	Capacity (MW)
2033	4	2640
2034	4	2640
2035	3	1980
2036	4	2640
2037	6	3960
2038	6	3960
2039	2	1320
2040	7	4620
Total	36	23760

Figure 2: Life cycle GHG emission intensity of electricity generation methods (WNA, 2017)

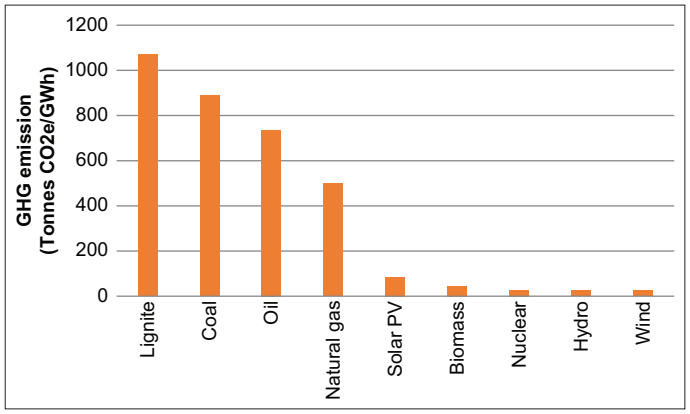
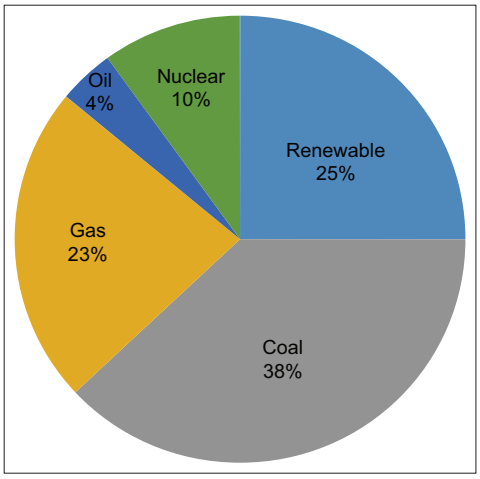


Figure 3: World energy mix -2017



announced by many countries. In year 2018, India, China, and Southeast Asia headed the overall increase in coal-fired power generation. China's electricity demand was 8% while 4% demand was met by coal power. The electricity generation in India rose by 5%, a slowdown from 2017 due to lower power demand growth. Since south East Asian countries are emerging economies hence the electricity demand growth is also on rise. However, with decreasing prices of renewable energy technologies with growing concern of climate change, the world is switching to renewable energy. With such emerging global energy scenario, energy policies and strategies for Pakistan are crucial for sustainable electricity supply. The objective of this study is to investigate the coherence between coal power penetration and climate change under three themes. SWOT analysis is strategic tool for achieving such objectives. It help define development strategy to maximize the potential strengths and opportunities while minimizing the effects of weaknesses and threats. SWOT allows better structured qualitative analysis of predefined issues. It is focused on change. It is therefore more dynamic and thus better able to identify changes that improve policy making. SWOT also has certain limitations. It is subjective even if an analysis is well structured. Consensus about its results is difficult to achieve. To better achieve consensus on key parameters, Delphi approach is very helpful before SWOT analysis is done. Therefore SWOT analysis has been performed in combination with Delphi to get proper outcomes which is the ultimate objective and motivation of this study.

The organizational structure of this study is as follows. Section 2 presents the literature review. Methodology is explained in section3. Results and discussion are presented in section 4. Section 5 concludes the study with policy recommendations.

2. LITERATURE REVIEW

To evaluate the emerging scenario of coal power generation, strategic analysis is required so that correct policy decisions can be made. SWOT analysis provides an excellent basis for strategy formulation when it is used properly, and Delphi approach is generally used in policy making and other critical issues where different expert respondents reveal their views prior to reach in a unanimity It is generally believed that any industry's strengths and weaknesses exhibit the industry's interior characteristics and can be well-ordered while an industry's opportunities and threats are seen by external factors on which the industry has no mechanism to regulate but can respond to its own improvement (Zhao and Hong, 2012). Since use of SWOT in energy analysis is a recent phenomenon, however it has been done for strategic energy planning. Many researchers have conducted studies for strategic planning of organization with SWOT approach alone or in combination with some other tools. Photo voltaic solar development of Africa was analyzed with SWOT tool and it was discovered that Africa has abundant prospective to exploit solar energy with the cooperation of China and international cooperation within framework of Belt and Road Initiative (BRI) (Lei et al., 2019). The conflicting outlooks for energy mix in Association of South East Asian Nations (ASEAN) emphasized the impact of fossil fuel dominated outlook when compared with its aspiration to change toward green energy strategies using SWOT analysis methods (Shi, 2016). SWOT analysis for energy sector was conducted in Turkey and study suggested an integrated hybrid methodology for the analysis of Turkeys energy alongside ANP and weighted fuzzy techniques for order performance by similarity and analyzed the energy strategy alternatives and priorities as a whole (Cayir et al., 2018).

Nuclear power generation was analyzed with SWOT technique and study concluded that generation of nuclear power is feasible option to reduce greenhouse gases along with other renewable energies. SWOT further revealed that, fossil fueled power plants should be integrated with Carbon Capture and Storage (CCS) technology) (Khalil, 2017). Canada's federal and provincial government's coherence while implementing the climate and energy policies have identified the challenges and prospects with SWOT analysis (Fertel et al., 2013). SWOT analysis of renewable energy of provinces of Sindh and Baluchistan of Pakistan while using Fuzzy Analytical hierarchy Process (Fuzzy AHP) found that that economic and sociopolitical are the two most important criteria and that wind has ample potential to generate electricity in both provinces (Wang et al., 2020). SWOT analysis of renewable energy of Pakistan 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 presence of competitive energy resources, policy implications and grid connection. The retainability of renewable energy is necessary for energy security and sustainability for Pakistan's power sector, such as significant advancement to attain energy security and sustainability (Kamran et al., 2020).

The issues of power generation sector of Pakistan in general, and the role of renewable energy in particular were examined and very precisely sustainable pathways have been determined with SWOT tool (Shakeel et al., 2016). To validate the outcomes of SWOT findings and attaining quantitative analysis, many researchers have used Delphi tool alongside SWOT. Delphi approach is widely used as an effective method in long term planning related to sustainable development (Pawlowski, 2010). Delphi tool is also employed for fore sighting. Foresight is about describing the variety of potential futures, in order to allow players, especially stakeholders, to prepare for this variety and to contribute to shape the outcomes (Celiktas and Kocar, 2010). Delphi approach is a structured group interaction that proceeds through multiple rounds of opinion collection and anonymous feedback (Tavana et al., 2012). Delphi method is nowadays widely applied as a valuable foresight tool (Czaplicka-Kolarz et al., 2009). Delphi practitioners employ this method primarily in cases where judgmental information is indispensable, and typically use a series of questionnaires interspersed with controlled opinion feedback (Monir and Hossain, 2015).

3. METHODOLOGY

SWOT-Delphi hybrid approach was applied to evaluate the prospects and possible outcome of such significant addition of coal fired power in energy mix of Pakistan. SWOT is useful for strategy formulation. Delphi approach help in reaching to consensus on critical issues

in diverse environment. The feedback regarding weightage of anticipated issues were collected by sending questionnaire through online medium in two rounds. In first round, out of 80 participants, 38 responded followed by 40 in second round. The respondents were identified and selected on the basis of their expertise and experience in the field of coal power generation and author's direct investigation prior to find out the power generation sector's strength, weakness, opportunities and threats. Secondary data was collected from different national and international organizations, newspapers, electronic materials, and research journals. By integrating the primary and secondary data, a strategic plan was formulated in SWOT analysis to find internal strengths and weaknesses alongside external factors, recognizing its future prospects and gravities of coal power in Pakistan's power sector.

3.1. SWOT Analysis

SWOT is a strategic planning tool. SWOT analysis is a methodology allowing understanding and planning to use their strengths to exploit opportunities to recognize and repair or avoid their weakness and to defend against or sidestep any unknown threat. SWOT investigation has been compiled in Table 4. SWOT analysis comprising of four elements are categorized into main two factors i.e. internal and external factors. Three themes have been selected such as energy security, energy efficiency and environmental sustainability as shown in Figure 4. The variables of each theme were identified with the help of literature in a way that if internal factors are favorable than it is considered as strength and in case of unfavorable, than it is weakness. Similarly in external factors, if it is favorable, it is an opportunity and for unfavorable, it is regarded as threat.

3.2. Delphi Method

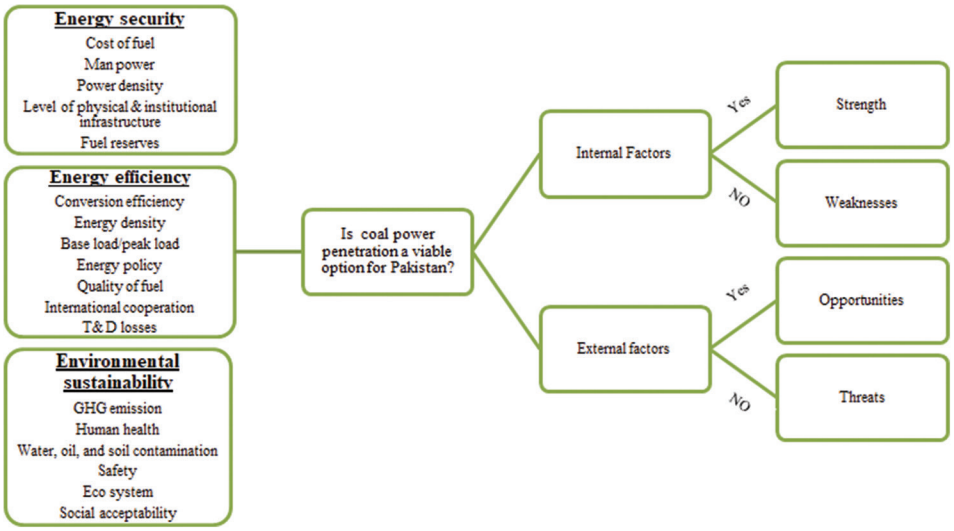
Delphi method is a process to make a decision, based on the survey of respondent's judgment in weight based of any undecided topic. It is generally used in policy making and other critical issues where different expert respondents reveal their views prior to reach in unanimity. Delphi method is nowadays widely applied as a valuable foresight tool. In this study, the Delphi method was employed by following procedures:-

- Experts from the coal fired power plants 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 coal power generation.
- The Delphi statements were developed by the authors and pursued through a number of sequential questionnaires.
- Participants were asked to provide their judgment on strengths, weaknesses, opportunities and threats of coal fired power plants.

Table 4: SWOT investigation of coal fired power generation

STRENGTH
• Huge reserves of coal • Less initial investment cost • Strategic importance of coal due to rising conflicts in the region • Base load plants
WEAKNESSES
• Thar coal has high moisture content • Water avalibility issue at site of coal mines • Lack of coherence between coal exploitation and climate policy. • Upfront tariff ranges from 8 to 9.7 US cents per unit shows serious neglect on the part of regulator
OPPORTUNITIES
• Thar Coal has the potential to convert to gaseous products and liquified fuels with good yield of products • Under vision 2030 strategic plan, Pakistan will increase coal power generation up to 19910 MW by 2030 • Deploying more advanced technologies could cut 2 giga tonns of CO2 emissions • High Effeciency Low Emission (HELE) technologies are commercially available
THREATS
• Adverse impacts on land, soil, and air • Fossil fuel depletion • Parameters such as effeciency project cost and O & M costs have been neglected by the NEPRA • CO2 effects on human health

Figure 4: SWOT synthesis



- The range of participant's opinions has been identified by Likert Scale.
- The extreme opinions were reassessed by the participants in second round.
- Finally, SWOT strategy was formulated prior to proper evaluation of coal power generation.

4. RESULTS AND DISCUSSION

SWOT Delphi hybrid approach has been applied to identify the outcome of coal power penetration in energy mix of Pakistan. The Delphi approach adopted in this study is discussed in the following sub section.

4.1. Delphi Approach

A Delphi method was used to conduct the survey of taking the expert opinions before the suggestion of future strategic plan of coal power generation. Expert's evaluations were weighted by Likert Scale. In this study, the Likert scale was considered from 1 to 5 points. Each point's remark is documented in Table 5. The expert's opinions in the field of strengths, weaknesses, opportunities, and threats were quantified based on expert's weighted evaluation and is shown in Table 6.

The majority of respondents were from academia and industry followed by government organisations and research instititutions as shown in Figure 5.

The authors referred same energy experts to rate some main points in line with the SWOT identification and for the analysis, weights on a scale of 1 to 5 were attached to highlight the importance and possible implication of the factors mentioned to the system. An aggregate view of their opinion is investigated in Table 7 and Figure 6.

4.2. SWOT Analysis

The strengths, weaknesses, opportunities and anticipated threats to coal power generation are elaborated in the following sub section.

Figure 5: Distribution of the Delphi survey participants according to their significance

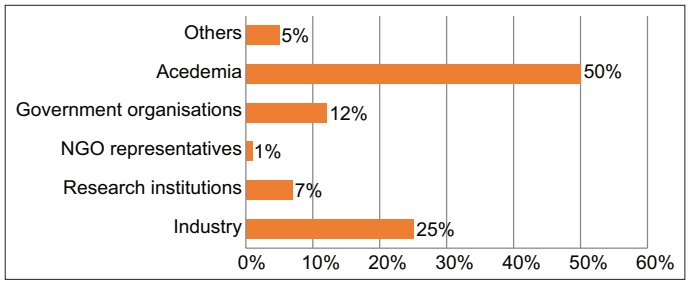


Table 5: Likert scale rating

Point	Remarks
1	Strongly diagree
2	Disagree
3	Undecided
4	Agree
5	Stongly agree

4.2.1. Strengths

4.2.1.1. Huge reserves of coal

As per World Energy Council, Pakistan's total coal reserves are 185 billion tons. Out of these reserves, 175 billion tons are from Thar of district Tharparkar

Sindh province of Pakistan. 660 MW capacity of Thar power plant has started generation of electricity from Thar coal. 7000 MW of more electricity will be generated from Thar coal in next phase. This huge resource of coal alone is sufficient to meet entire future electricity demand of Pakistan for at least 100 years.

4.2.1.2. Less initial investment cost

The initial cost of coal based power generation is less as compared to nuclear or hydro power. That is why coal power generation source offers immediate solution to energy need of Pakistan in terms of economy and early completion of

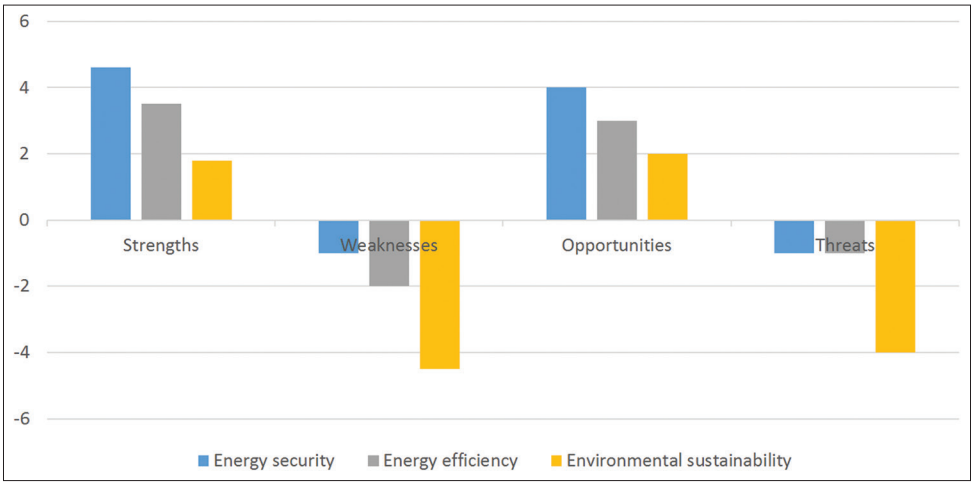
Table 6: The Delphi statements and expert evaluation of coal power generation

Power generation technology	Strengths	Weakness	Opportunities	Threats	Round	Respondents	Mean
Coal	Huge reserves of coal Less initial investment cost Strategic importance of coal due to rising conflicts in the region Base load plant	Thar coal has high moisture content Water availability issue Lack of coherence between coal exploitation and climate policy. Upfront tariff ranges from 8 to 9.7 US cents per unit shows serious neglect on the part of regulator	Thar Coal has the potential to convert to gaseous products and liquified fuels with good yield of products Under vision 2030 strategic plan Pakistan will increase power generation up to 19910 MW by 2030 Deploying more advanced technology could cut 2 giga tons of CO_2 emissions High efficiency low emission (HELE) technologies are commercially available	Serious impacts on land, soil, and air Fossil fuel depletion Parameters such as efficiency project cost and O and M cost have been neglected by NEPRA	1 2	38 40	4.5

Table 7: Aggregate rating on SWOT analysis by experts of coal power generation

	Energy security	Energy efficiency	Environmental sustainability	SWOT (valued)	
Strengths	4.6	3.5	1.8	9.9	∑SW= 2.4
Weaknesses	−1	−2	−4.5	−7.5	
Opportunities	4	3	2	9	∑OT= 3
Threats	−1	−1	−4	−6	
SWOT Factors (valued)	6.6	3.5	−4.7		

Figure 6: Pakistans coal power generation SWOT scenario



projects. Since Pakistan suffered from power deficit over the last two decades, therefore many thermal power plants were commissioned over the last decade to meet the immediate demand of electricity.

4.2.1.3. Strategic importance of coal due to rising conflicts in the region

Pakistan is situated in a region, where regional tension is growing. In the east, relations with India are fragile, Afganistan in the west is another flash point for Pakistan. Iran and Saudi Arabian conflict is deepening and Middle East is surrounded by clouds of war. In this environment, the supply of imported fuel and LNG can be disrupted any time endangering the energy security. Therefore presence of huge reserves of indiginous coal is a blessing for energy deficient country like Pakistan.

4.2.1.4. Base load power generation

Coal based power plants fall in the category of base load power sources due to low fuel cost and steady state power. They operate continuously to encounter the minimum level of power demand throughout the day. Base load plants are usually large-scale and are key components of an efficient electric grid. Coal fired power plants covers that area of load in the load duration curve which is required for 24 h of a day. Therefore the reliability of power generation is enhanced.

4.2.2. Weaknesses

4.2.2.1. Thar coal has high moisture content

The coal in Thar region is lignite. Moisture content in Thar coal is around 44.3%. The efficiency of power generation is reduced with increase in moisture content. Capital cost is added for the equipment required to burn the coal. The total moisture in coal comprises the intrinsic and surface moisture, which directly affects its specific energy and efficiency of the boiler due to loss of latent heat of water with the flue gas. Boiler efficiency is dropped by 1% with increase of 1% moisture drops.

4.2.2.2. Water availability issue

Water for Thar power projects is not available at site. Therefore government has built carrier from Left Bank Outfall Drainage (LBOD) Spinal Drain to Thar coal power generation units. Tube wells and RO plants are under construction to ensure 100 cusecs of water at power generation site. To ensure water supply adequately, water reservoir is being built at Nabisar and water supply through pipeline is also under way. Ensuring water supply for power plant will however increase the cost of generation.

4.2.2.3. Lack of coherence between coal exploitation and climate change policy

Pakistan lacks coherence between coal exploitation and climate change policy. There is no coordinated national energy strategy beyond reliance on market forces. The decisions are derived from immediate needs of energy and availibility of coal.

4.2.2.4. Upfront tariff ranges from 8 to 9.7 US cents per unit shows serious neglect on the part of regulator

National Electric Power Regulatory Authority (NEPRA) has increased the tariff by about 20 percent, and fixed an upfront tariff of 8 to 9.67cent per unit for coal power plant of 200 MW, while 8 to 9.54 cent/unit for a 600 MW capacity power plant, and 8 to 9.11 cent/unit for coal power plant of 1,100MW capacity. NEPRA also decreased the efficiency of coal power plants by 3% which reached at 42%. This negligence on the part of regulator will have negative impacts on the coal power generation sector in terms of affordability and efficiency.

4.2.3. Opportunities

4.2.3.1. Thar coal has the potential to convert to gaseous products and liquefied fuels with good yield of products

Thar coal is in the series of lignite B to bituminous with moderately low sulfur and ash content, it can be appropriately transformed to coal gas. This gas is combination of carbon monoxide, carbon dioxide, ash and water vapors. Similarly Thar coal can be categorized as kerogen type II and is similar with good quality oil shale. Due to substantial amount of extractable organic matter (EOM), the Thar coal can be used for liquefaction. With the help of modern techniques and resources, this huge coal can be utilized for the energy needs of Pakistan.

4.2.3.2. Under vision 2030 strategic plan, Pakistan will increase power generation up to 19910 MW by 2030.

Pakistan has great opportunity to utilize indigenous coal to generate electricity to meet future energy requirements. Government has planned to generate 19919 MW of electricity with local and imported coal by 2030 under strategic plan. With the addition of 19910 MW of electricity by coal, its energy security will be enhanced and reliance on imported fuel will be reduced.

4.2.3.3. Deploying more advanced technologies could cut 2 giga tons of CO_2 emissions

With employment of super critical turbines in coal based power generation, it is estimated that Pakistan will be able to reduce 2 giga tons of CO_2 emissions. On account of being signatory to various climate protocols, Pakistan can get credit to this significant reduction and subside the possible criticism for commissioning coal based thermal power plants.

4.2.3.4. High efficiency low emission (HELE) technologies are commercially available

Employing HELE technologies such as super critical, ultra-super critical and IGCC alongside Carbon Capture and Utilization Storage (CCUS), near zero emission can be achieved. HELE technologies have profound role in reducing GHG emissions from entire power sector by 20%. Such modern technologies can reduce toxic pollutants such as Nitrogen Oxides (NOx), Sulpur Oxides (SOx) and Particulate Matter (PM) along with CO_2 emissions. Significant reduction of these toxic pollutants has additional advantage of improving the air quality and minimizing health concerns. Pakistan has an opportunity to take advantage of such modern technologies in coal based power plants in future. Deploying such modern technologies will also enhance the plant efficiency.

4.2.4. Threats

4.2.4.1. Adverse impacts on land, soil, and air

Coal based power plants emit CO_2, CO, SOx, NOx, particulate matter and unburned carbon. All these substances are toxic to environment. CO_2 and NOx are greenhouse gases and are culprit to global warming. SOx and NOx are responsible for acid rain and harming vegetation and human health. Particulate matter is causing lung disease. All these emissions degrade land, soil and air quality. Therefore coal based power generation is generally regarded as unsustainable sources of energy unless serious mitigation measures are taken.

4.2.4.2. Fossil fuel depletion

All the fossil fuels around the globe are finite. Therefore ruthless use of fossil fuels will lead to depletion of all such fuels including coal. Pakistan has finite reserves of fossil fuels like natural gas, oil and coal. Reserves of natural gas are shrinking quickly and it is anticipated that they will be depleted in next 15 year if the use of this resource is utilized on current scale. Although Thar coal reserves are 175 billion tons, only two billion tons are recoverable. Therefore dependence on any fossil fuel for full filling energy need can jeopardize the energy security of Pakistan.

4.2.4.3. Factors like project cost, O and M cost and efficiency have been neglected by NEPRA

In an attempt to attract investment in coal projects, the larger interest of efficiency in coal-power generation has been utterly ignored by regulator, pushing upfront tariffs higher bringing about unsustainable energy. The proposed tariff for 220 MW, 660 MW

and 1000 MW were US Cent 9.7, 9.5 and 9.12 respectively, and these can best be called as a case of miscalculation and gross professional inattention by the NEPRA. The severe negligence on the part of regulator has put burden on the consumers in terms of non-viable tariff. Disregarding the international good practices in coal power generation can result in to externality cost in the form of carbon foot print.

4.2.4.4. CO_2 effects on human health

Carbon dioxide emissions impact human health by shifting oxygen in the atmosphere. Breathing becomes more difficult as carbon dioxide levels rise. In closed areas, high levels of carbon dioxide can lead to health complaints such as headaches. Carbon dioxide levels may indicate high levels of other harmful air pollutants such as volatile organic compounds which contribute to indoor air pollution.

SWOT and Delphi methods were used as mutually beneficial tools. While SWOT analysis supports the decision making, Delphi deals with the relative importance of the SWOT aspects. By incorporating SWOT with Delphi mutual weighting of SWOT aspects, and the assessment of alternative strategic decisions, the policy framework can be made.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

SWOT study of coal fired electricity generation is based on three themes energy security, energy efficiency and environmental sustainability. This study attempt to obtain a clearer and fairer picture of Pakistan's coal power generation, its comparative strengths and weaknesses by anticipating future trends, opportunities and threats.

In this context, SWOT analysis of coal power has identified that Pakistan aims to utilize coal potential primarily based on the basis of abundant reserves. The study reveals that there is a no coordinated national energy strategy energy security. Country lacks long term strategy for sustainable resource management. High moisture content in indigenous coal, lack of coherence between coal exploitation and climate policy are major weaknesses in the system. Deployment of modern tools such as High Efficiency Low Emission (HELE) technologies and conversion of coal to gaseous and liquefied fuels offer promising opportunities for coal exploitation to meet energy demand. The prominent threat is the environmental degradation and GHG emissions. To improve overall performance of this sector, some major reforms are proposed such as

- Improved regulatory regime,
- Market oriented mechanism and integrated energy policies.
- Bringing environmental compliance with international standards will boost confidence of international donor agencies for investment in this sector.
- An effective compliance regime should be in place to make sure that coal-fired power plants are operated and maintained with acceptable level of pollutants in the atmosphere.
- Employment of low carbon generation options needs to be assessed.
- Gradual phase out of generation from less-efficient subcritical coal units.
- The efficiencies of new coal-fired unit should be consistent with global best practices such as supercritical or ultra-supercritical technologies.
- The fleet of old coal power plants must be modernized with efficiency improvements.
- New coal power plants should be built on Carbon Capture, Utilization and Storage (CCUS) approach.
- To improve coherence between coal exploitation and climate policy of Pakistan.

With increase in population, urbanization, improved living standards and economic development, the electricity demand is anticipated to increase manifold in years to come. To meet anticipated demand, power generation from coal remains an engaging choice for Pakistan. The conducted SWOT analysis with policy recommendations can establish a conversation with all stakeholders to institute useful and effective recommendations and execution strategies to exploit coal for power generation in conformity with climate change initiatives.

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