UDC 622.8:622.71 5 DOI: 10.70769/2181-7383.MBU.1(104).2026.8

CURRENT STATUS AND FUTURE PROSPECTS OF COAL MINING IN PAKISTAN

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Abstract. *The coal mining sector in Pakistan is a key contributor towards the socio-economic uplift of the mineral sector, as well as the country's energy needs and social security. Data scarcity related to the mining accidents results in recurring fatalities and injuries, costing lives, money, and time, making the ongoing coal mining operations more risky, expensive, and complex. Research regarding the underlying factors culminating in accidents is indispensable to understanding the subject matter well and overcoming it by devising effective strategies accordingly. Hence, without the provision of relevant data, it becomes impossible to investigate the underlying dynamics, consequences, and remedial measures of mine accidents. Furthermore, the lack of will to adopt technology further adds to the problems of the mining industry. This study aims to present different aspects that directly and indirectly affect the safety of the underground coal mining industry in Pakistan, namely data scarcity, lack of research, and application of technology. In addition, this study presents the predicted situation of the mining sector in the next 30 years in Pakistan based on the exponential triple smoothing method analysis. Moreover, effective strategies are also proposed to overcome potential safety problems in Pakistan's coal mining industry.*

Keywords: *coal mining sector in Pakistan; data scarcity; research gap; safety issues in Pakistan's mining industry; lack of technology*

Acknowledgments: *Our sincere thanks go to the anonymous reviewers for their valuable comments and suggestions.*

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

POKISTONDA KO'MIR QAZIB OLISHNING HOZIRGI HOLATI VA KELAJAK ISTIQBOLLARI

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Annotatsiya. *Pokistonda ko'mir qazib olish sohasi mineral resurslar sektorining ijtimoiy-iqtisodiy rivojlanishida, shuningdek mamlakatning energiya ehtiyojlari va ijtimoiy xavfsizligini ta'minlashda muhim o'rin tutadi. Tog'-kon avariyalari bo'yicha ma'lumotlarning yetishmasligi o'lim va jarohatlanish holatlarining takrorlanishiga olib kelib, inson hayoti, moliyaviy resurslar va vaqt yo'qotilishiga sabab bo'lmoqda hamda amaldagi ko'mir qazib olish jarayonlarini yanada xavfli, qimmat va murakkab qilmoqda. Baxtsiz hodisalarga olib keluvchi asosiy omillar bo'yicha tadqiqotlar mavzuni chuqur anglash va muammoni samarali strategiyalar ishlab chiqish orqali bartaraf etish uchun zarur hisoblanadi. Shu bois, tegishli ma'lumotlar mavjud bo'lmagan sharoitda tog'-kon avariyalarining ichki mexanizmlari, oqibatlari va ularni bartaraf etish choralarini o'rganish imkonsizdir. Bundan tashqari, zamonaviy texnologiyalarni joriy etishga bo'lgan yetarli intilishning yo'qligi tog'-kon sanoatidagi muammolarni yanada kuchaytirmoqda. Mazkur tadqiqot Pokistondagi yer osti ko'mir qazib olish sanoatida xavfsizlikka bevosita va bilvosita ta'sir etuvchi turli jihatlarni, xususan ma'lumotlar tanqisligi, ilmiy tadqiqotlar yetishmasligi hamda texnologiyalarni qo'llash masalalarini yoritishga qaratilgan. Shuningdek, eksponensial uch martalik silliqlash usuli asosida Pokistonda keyingi 30 yil davomida tog'-kon sektorining kutilayotgan holati prognoz qilinadi. Bundan tashqari, Pokiston ko'mir qazib olish sanoatida yuzaga kelishi mumkin bo'lgan xavfsizlik muammolarini bartaraf etish uchun samarali strategiyalar taklif etiladi.*

Kalit so'zlar: *Pokistonda ko'mir qazib olish sohasi; ma'lumotlar tanqisligi; tadqiqotlar bo'shligi; Pokiston tog'-kon sanoatida xavfsizlik muammolari; texnologiyalar yetishmasligi.*

Pakistan ranks 7th among the top coal-rich countries [1], with about 185 billion tons of reserves. However, the sector has remained underdeveloped for years due to limited financial resources and technical barriers [2]. Table 1 shows the total coal resources in Pakistan (in billions of tons). The coal varieties range from lignite to sub-bituminous and bituminous coal. It contains some of the largest lignite deposits in Asia; lignite-bearing varieties make up approximately 97% of the blend [3]. Annual production stood at 4 million tons in 2018; after the development of Thar Coalfield's Block-II, production reached approximately 7 million tons in 2020 [6]. Howev-

er, an additional 4 million tons need to be imported annually to meet the country's energy requirements [7]. The mining sector in Pakistan is among the most underdeveloped and, even today, has not been accorded the status of an industry [8]. Immense potential exists for coal-fired power generation, but the authorities and the government have yet to exploit and utilize the resource effectively for socio-economic growth [9]. Current production remains very low compared to neighboring countries such as China, India, and Bangladesh, underscoring the general energy crisis in Pakistan. Shortfalls in generation capacity are evident in daily outages of approximately 8 to 12 hours for households and industry [10,11]. In 2011–2012, coal accounted for about 10% of the energy mix, with the cement and brick-kiln industries accounting for 60% and 40%, respectively, of coal use [12]. As such, coal remains a significant driver of economic growth, but mining conditions continue to be considered among the most dangerous.

The scarcity of data in mine accidents has been responsible for the continuous death toll in the sector, having touched lives, the economy, and time, making coal mine practices harder to control and unsustainable in their current form. During the last decade, the mining sector in Pakistan has recorded the highest impact of safety concerns, with an increase in fatal mine accidents. With data showing that 414 coal miners have lost their lives in varying incidents such as suffocation, gas explosion, roof fall, and many others, with roof fall being the leading reason, in the period between 2010 and 2019 [13,14]. The year 2020 alone witnessed the death of around 100 coal miners in 72 accidents in Balochistan [15]. The figure could be higher, with estimates by the Pakistan Central Mines Labor Federation indicating that the death toll could be anything between 100 and 200 annually. The recent data indicates that over 318 miners have lost their lives in Balochistan in the last some years [16]. Therefore, data scarcity has led to a situation where there is little to no information on some issues, which has made it hard for any researcher to fully understand the issue at hand. This has thus resulted in major socio-economic and sustainability issues in the country, as there is little to no research aimed at ensuring that the origin of the issues is identified. Identified issues need proper understanding to avoid missteps in ensuring that appropriate action is taken; this is possible if there is existing information to aid in properly understanding. Lack of information on issues has, therefore, acted as a major obstacle, especially in the country's coal mining sector, mainly due to issues of accessing available information from the authorities and online databases. As a result, there is a major lack of research aimed at ensuring that this issue is understood. This has affected this sector of the country's mining sector, resulting in major losses. Another major issue facing this sector is a lack of technology and a lack of interest in embracing innovations. The world over, the mining sector has mainly adopted modern and advanced technological means to extract mineral resources in a safe and efficient manner. However, in Pakistan, mining operations still rely on more primitive and outdated technologies.

The sector not only becomes more unsafe but also more expensive and complicated. Many researchers have carried out studies on mining safety [1,2,4,17,18]; However, only managerial direction was more stressed in their studies rather than addressing the latest redesign of mining methods in the country's mines. This study aims to discuss various aspects of the mining sector, namely data scarcity, lack of research, and lack of technology, which often lead to serious safety issues in Pakistan. In addition, the exponential triple smoothing (ETS) forecasting method was used for the first time to understand the situation of the mining sector in the next 30 years in coal mines in Pakistan. This study attempts to understand the influencing factors that lead to recurring safety problems in the coal mining sector of Pakistan. To the best of the author's knowledge, the published literature does not report any such study covering this aspect of Pakistan's coal mining industry.

Table 1

Total coal resources in Pakistan [19]

Province / Coal Field	Measured	Indicated	Inferred	Hypothetical	Total
SINDH					
Lakhra	244	629	455	—	1,328
Sonda-Thatta	60	511	2,197	932	3,700
Tharuck	106	310	907	—	1,323
Others	82	303	1,881	—	2,266
Thar	3,407	10,323	81,725	80,051	175,506
Sindh Sub-Total	3,899	12,076	87,165	80,983	184,123
BALOCHISTAN					
Khost-Sharing-Harnai	13	—	63	—	76
Sor-Range/Degari	15	—	19	16	50
Duki	14	11	25	—	50
Mach-Abegum	9	—	14	—	23
Pir Ismail Ziarat	2	2	8	—	12
Chamalong	1	—	5	—	6
Balochistan Sub-Total	54	13	134	16	217
PUNJAB					
Eastern Salt Range	21	16	2	145	235
Central Salt Range	29	—	—	—	29
Makerwal	5	8	9	—	22
Punjab Sub-Total	55	24	11	145	235
TOTAL	**4,008**	**12,113**	**87,189**	**81,144**	**184,575**

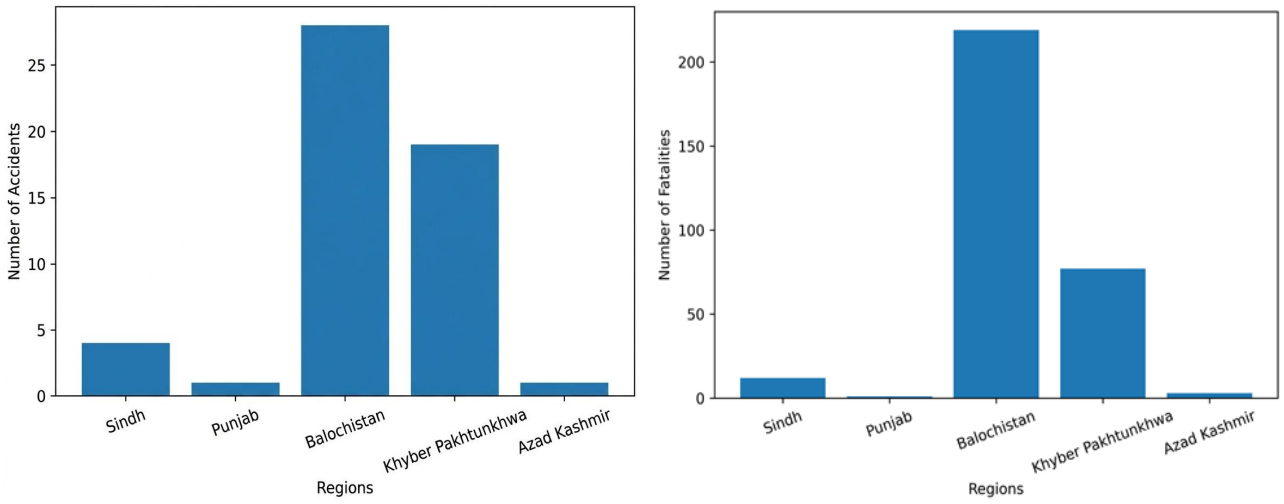

Fig.1 Province-wise accidents and fatalities distribution from 2010 to 2018.

Current Status of Mining

Coal mining is a highly hazardous occupation due to its ability to be prone to a large number of accidents and fatalities [18,20]. The common methods of coal mining in Pakistan are the room and pillar and longwall. The industry exhibits promising prospects with an average annual growth potential of approximately 2-3%. It operates over 5,000 active mines, hosts 50,000 SMEs, and provides direct employment to around 300,000 workers [21]. The deepest coal mining operations in Pakistan have surpassed the 1,000 m [22-24]. An analysis was conducted regarding the statistical study concerning accidents and fatalities in coal mine accidents in Pakistan from the period ranging from 2010 to 2018. Fig. 2 shows that from 2010 to 2018, a total of 53 accidents resulted in 312 deaths in underground coal mines in Pakistan. The data is taken from academic, journalistic, and industrial sources. From Fig. 2, it can be deduced that major fatal accidents occurred in areas including Balochistan, where there were 28 accidents causing 219 fatalities, and Khyber Pakhtunkhwa, where there were 19 accidents causing 77 fatalities, compared to other territories in Pakistan. On average, 6 accidents result in 35 fatalities every year. In Fig. 2, there are mine collapses that caused about 36% of accidents and 51% of fatalities, totaling 53 accidents and 312 fatalities. Gas explosion ranked 2nd, causing about 19% of accidents and 17% of fatalities, then there were mine blasts that ranked 3rd, causing about 13% of accidents and 16% of fatalities. There was also an accumulation of gases, which caused 11% of accidents and 6% of fatalities, falling stone, causing 10% of accidents and 3% of fatalities, and others, causing 10% of accidents and 7% of fatalities. From the analysis of various accidents, it is deduced that one of the elements that culminated in accidents includes negligence and breach of the effectiveness of adequate safety measures by the administration. In addition, mine collapse, mine blast, and gas explosion can be identified as some of the major causes of fatalities due, of course, to the lack of attention given to the safety measures which must be strictly implemented by the government of Pakistan. However, it must be noted here that the data provided focuses solely on the causes of accidents resulting in specific fatalities, while completely lacking any information regarding the underlying reasons for these accidents.

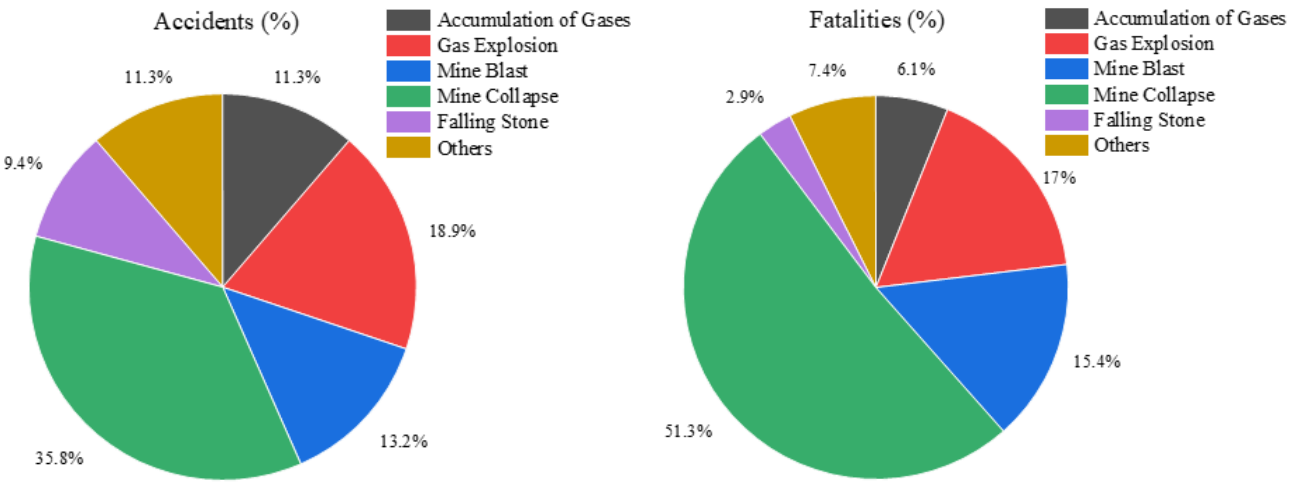

Fig. 2 Cause wise (a) accidents and (b) fatalities from 2010 to 2018 [14].

Future Mining Strategies for Coal in the Country

Keeping in view the overall scenario, it is evident that since Pakistan's independence, coal mining technology has never advanced and remains stuck in a primitive and backward stage, unable to achieve satisfactory results. Except for a few mines, coal extraction still relies on manual labor and animal power. Roof support measures using wooden props are both inadequate and insufficient. This unacceptable practice not only leads to low production efficiency but also causes the miner accident fatality rate to continue rising. As a nation rich in coal resources, Pakistan currently faces a severe energy crisis—partly due to insufficient emphasis on coal development, forcing the country to rely on coal imports. Therefore, effective strategies should be devised by concerned authorities and the government to improve the potential coal mining technologies in Pakistan as;

(1) The relevant authorities and/or online databases must ensure data availability to overcome the nationwide data scarcity, facilitate researchers to fill the research gaps, and suggest effective and appropriate mining technologies for coal mining in Pakistan. According to the literature, Pakistan imports about 4 million tons of coal every year to meet the needs of the country; therefore, the expenditure on coal import should be saved and diverted to research and technology development, and other aspects.

(2) Since Pakistan is a low GDP country, and the majority of coal mines are non-mechanized; thus, semi-mechanized systems should be adopted instead of full mechanization, especially in underground coal mines, to increase the efficiency of coal production and overcome escalating accidents and fatalities. As presented in Fig. 3, the number of accidents and fatalities associated with mine collapses or roof falls can be greatly reduced by adopting a semi-mechanized roof support system in the working area. Furthermore, by doing this, coal productivity can be increased several times compared to the primitive coal mining methods. In addition, as an example, recent research [25,26] has proposed more specific, economic, and safe coal production technologies to develop enormous coal reserves in the Thar coalfield in Pakistan.

(4) Ensuring a safe working environment for miners should be the priority. The mechanization of coal mines can greatly improve production by substituting manual coal cutting efforts and can reduce the coal loss and the number of accidents and fatalities. Moreover, based on the study of mining and geological conditions of Pakistan's coal deposits, the possibilities of moving to a safer full or semi-mechanized pillar mining must be analysed, rather than manual coal extraction (using a miner's pick and shovel).

(5) Inadequate ventilation design can lead to the accumulation of toxic gases and deaths associated with gas explosions; therefore, it is recommended that ventilation be properly designed by maximizing the capacity of fans to ensure proper air circulation, or hazardous areas should be permanently closed and isolated from the working environment. Otherwise, operations in such mines can cause serious safety issues and affect the welfare of coal miners.

(6) Illegal mining and inadequate implementation of internationally suggested mining standards and practices are other issues in the Pakistani coal mining sector, which not only compromise the safety of the mining environment but also reduce the coal productivity of the country. Therefore, ensuring work compliance with the suggested mining laws is recommended.

(7) Based on the literature review and observation during the coal mining visits, made clear an acute lack of awareness in miners about the mining environment and safe mining practices. Additionally, a deficiency of personal protective equipment (PPE) was also observed. Prior to working in mines, the miners should be trained for a certain duration to deal with mining conditions and equipped with proper PPE. In parallel, adequate monitoring of risk factors is regularly suggested.

(8) Both public and private sectors are involved in coal mining operations in Pakistan. A significant number of coal mines run under the private sector are illegally operating in Pakistan. This practice leads towards neglecting human rights and safety standards, for example, underage coal miners, poor working conditions, lower wages, lack of proper equipment, and weak mine structures, etc. Coping with these

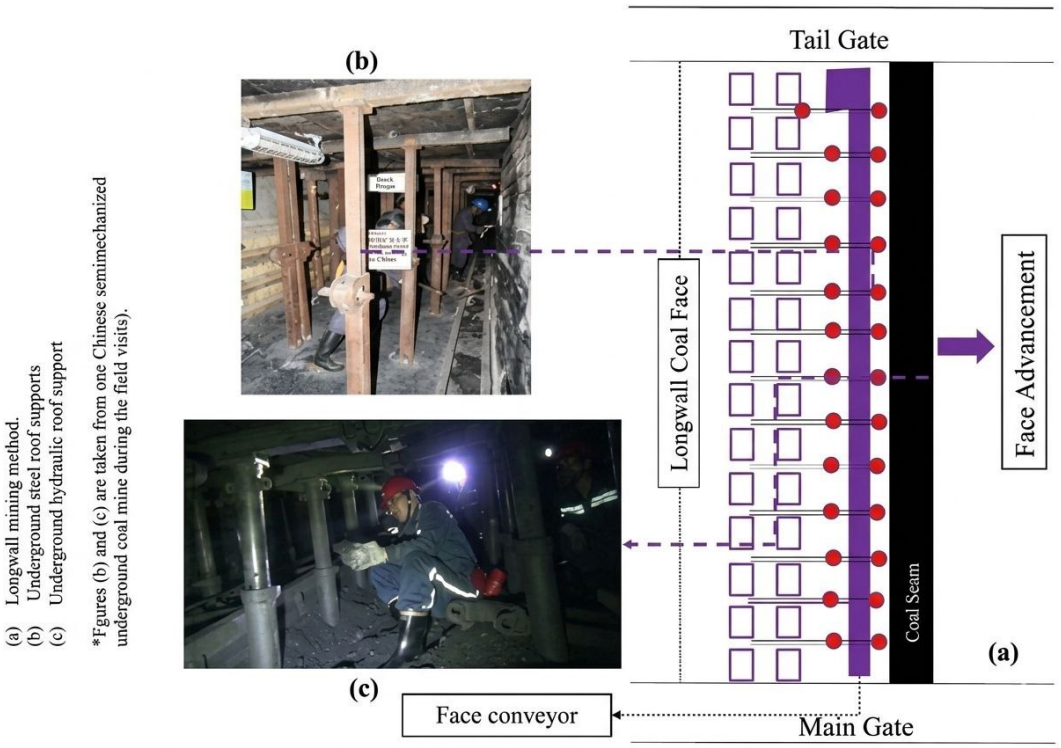

Fig. 3 Suggested arrangement of semi-mechanised longwall mining method in coal mines in Pakistan.

problems, all illegal coal mines should be regularised by the government for adequate checks and balances. Similarly, effective collaboration, like a public-private partnership (PPP), can improve mining safety and health conditions and introduce the latest mining technologies in Pakistan.

(9) Lastly, appropriate budgetary allocation towards the implementation and enforcement of relevant mining laws and regulations is needed to ensure safe mining in Pakistan.

Predicted Situation of the Mining Sector in the Next 30 Years in Pakistan based on Exponential Triple Smoothing Method

Fig. 4 represents the estimated annual coal production (million tons) from 2009 to 2048. As shown at the beginning of the figure, the graph from 2009 to 2018 shows the reported annual coal production; however, the coal production values from 2019 to 2048 are estimated future values for the next 30 years in Pakistan. Based on the exponential triple smoothing (ETS) evaluation, coal production is projected to increase from 3.51 (million tons) in 2009 to 7.55 (million tons) in 2048.

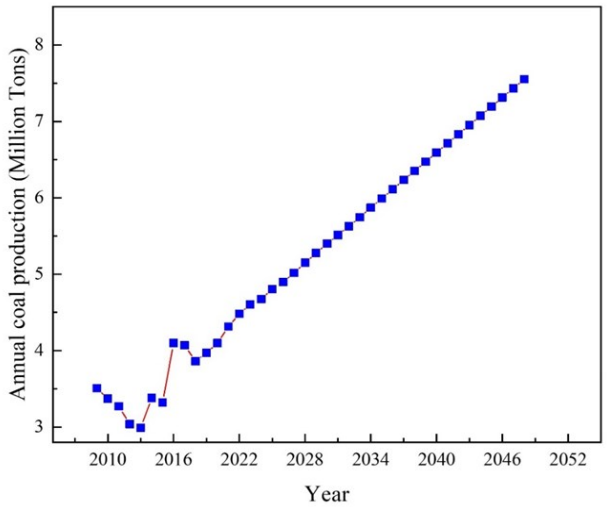

Fig 4 Estimated coal production in the next 30 years In Pakistan

Fig. 5 signifies the estimated annual consumption of coal (million tons) from 2009 to 2048 in Pakistan. According to the figure, the period from 2009 to 2018 shows reported values of coal consumption, while the values from 2019 to 2048 are the estimated future values of coal consumption for the next 30 years in Pakistan. Therefore, the future forecast shows that coal consumption is significantly increasing from 3.93 (million tons) in 2009 to 55.67 (million tons) in 2048. Despite the grim state of existing coal production, there is a positive indication that coal production will improve in the future, while according to ETS analysis, projected coal consumption is too high.

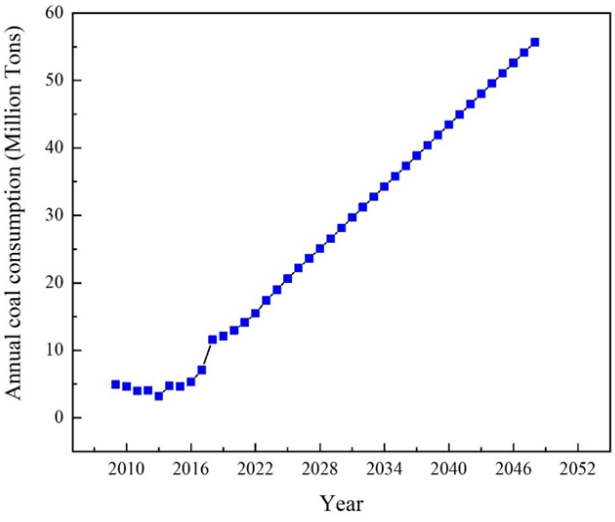

Fig 5 Estimated consumption of coal in the next 30 years in Pakistan

Fig. 6 represents the annual coal imports (million tons) from 2009 to 2048. The actual reported values of annual coal imports are mentioned starting from 2009-2018. On the other hand, according to ETS analysis, for 2019 to 2048 indicate the projected values for the import of coal for next 30 years. Thus, the coal import is projected to drastically increase from 1.42 (million tons) in 2009 to 49.40 (million tons) in 2048. Similarly, as indicated by ETS analysis, Pakistan will require a large quantity of imported coal in the future.

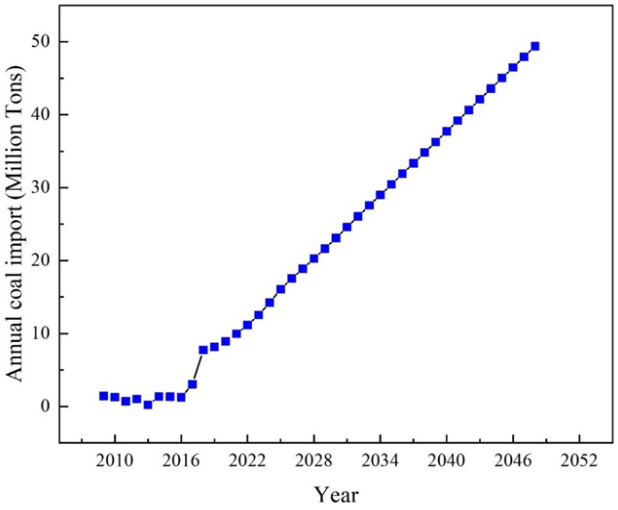

Fig. 6 Estimated coal import in the next 30 years In Pakistan

As mentioned earlier, Pakistan is a low GDP country, and in view of this, this study proposes that utilizing the domestic coal resources, rather than coal import, is significantly beneficial to the socio-economic development of the country. The development of local coal mines can not only address the country's coal demand but can also open up opportunities for stakeholders.

Conclusion

Coal, recognized globally as one of the most abundant and cost-effective energy sources, plays an integral role in development. Pakistan, today, is struggling to manage an energy crisis on an extensive scale, and coal can be used for electricity production. The coal mining sector in Pakistan plays a crucial role in the sustainable development of the mineral industry, as well as in the country's energy and social security. Furthermore, Pakistan's mines suffer from poor working conditions due to primitive operating methods and a lack of skilled labor. Mine collapses, explosions, and gas explosions are the primary causes of fatal injuries among Pakistani coal miners. The Pakistani government has failed to effectively implement necessary safety measures to reduce workplace risks for coal miners, with the absence of safety safeguards being particularly pronounced in Balochistan and Khyber Pakhtunkhwa provinces.

In conclusion, this study highlights the data scarcity, lack of research, and technology as factors leading to the recurring and severe safety threats in underground coal mines in the country. In addition, on the basis of this paper, it is pertinent for the stakeholders to take appropriate steps to improve the existing technology and conduct a reliable investigation on the effective application of modern mining meth-

ods in Pakistan's coal sector in the future. Finally, this study proposes that utilizing domestic coal resources is more beneficial to the socio-economic development of Pakistan, which is a low GDP country.

References:

1. N. M. Shahani, Z. Wan, M. Ali, B. Ullah, Detection and Monitoring of Underground Coal Mine Gases at Lakhra Coal Mines, Pakistan. 35th Annual International Pittsburgh Conference, Xuzhou, China (2018).
2. I. M. Jiskani, B. Ullah, K. S. Shah, S. Bacha, N.M. Shahani, M. Ali, A. Maqbool, A.R. Qureshi, Overcoming mine safety crisis in Pakistan: An appraisal. Process Saf. Prog. 38 (4), 1-5 (2019). https://doi.org/10.1002/prs.12041
3. M.F. Ullah, K. Mahmood, M.S. Akram, Coal mining trends and future prospects: A case study of Eastern Salt Range, Punjab, Pakistan. J. Himal. Earth Sci. 51 (2A), 87-93, (2018).
4. N.M. Shahani, M.J. Sajid, M.A. Brohi, A.R. Qureshi, L.B. Shahani, S. Bacha, B. Ullah, An empirical analysis of fatal accidents in the coal mines of Pakistan. In Proc. the International Conference on Energy, Resources, Environment and Sustainable Development, Xuzhou, Jiangsu Province, China. 726-73, (2019).

N.M. Shahani, M.J. Sajid, X. Zheng, M.A. Brohi, I.M. Jiskani, F.U. Hassan, A.R. Qureshi, Statistical analysis of fatalities in underground coal mines in Pakistan. Energ. Sources Part A. 1-16, (2020). https://doi.org/10.1080/15567036.2020.1841340

1. YCharts. Pakistan Coal Production. https://ycharts.com/indicators/pakistan_coal_production [accessed on 05/08/2022].
2. Pakistan Economic Survey. https://www.finance.gov.pk/survey/chapters_13/executive%20summary.pdf [accessed on 05/04/2022].
3. Businerss Recorder. Mining sector likely to get status of industry. https://www.brecorder.com/news/40188393 [accessed on 05/08/2022].
4. A. Khan, A. Mumtaz, G. Athar, Significance of indigenous coal in Pakistan's energy scenario. Significance of the coal resources of Pakistan Quetta. Geo. Survey of Pak. 173-188, (1990).
5. N.H. Mirjat, M.A. Uqaili, K. Harijan, G.D. Valasai, F. Shaikh, M. Waris, A review of energy and power planning and policies of Pakistan. Renew. Sustain. Energy Rev. 79, 110–127, (2017). https://doi.org/10.1016/j.rser.2017.05.040
6. A. Latif, N. Ramzan, A review of renewable energy resources in Pakistan. J. Glob. Innov. Agric. Soc. Sci. 2, 127–132, (2014). https://doi.org/10.17957/JGIASS/2.3.593
7. Malkani, M.S., 2012. A review of coal and water resources of Pakistan. Journal of Science, Technology and Development, 31 (3), 202-218.
8. IndustriAll Global Union (2019). 27 coalminers killed in Pakistan so far in 2019. https://www.industriall-union.org/27-coalminers-killed-in-pakistan-so-far-in-2019 [accessed on 09/08/2022].
9. Shahani, N. M., Sajid, M. J., Zheng, X., Brohi, M. A., Jiskani, I. M., Ul Hassan, F., & Qureshi, A. R. (2020). Statistical analysis of fatalities in underground coal mines in Pakistan. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 1-16.
10. Aljazeera (2021). Seven killed in southwest Pakistan coal mining disaster. https://www.aljazeera.com/news/2021/3/16/seven-killed-in-southwest-pakistan-coal-mining-disaster [accessed on 09/08/2022].
11. Business and Human Rights Resource Centre (2018). Pakistan: Over 318 workers killed in last eight years in coal mines in Balochistan. https://www.business-humanrights.org/de/neuste-meldungen/pakistan-over-318-workers-killed-in-last-eight-years-in-coal-mines-in-balochistan/ [accessed on 09/08/2022].
12. N.M. Shahani, M.J. Sajid, X. Zheng, I.M. Jiskani, M.A. Brohi, M. Ali, A.R. Qureshi, Fault tree analysis and prevention strategies for gas explosion in underground coal mines of Pakistan. Min. miner. depos. 13 (4), 121-128, (2019). https://doi.org/10.33271/mining13.04.121
13. N.M. Shahani, M.J. Sajid, X. Zheng, I.M. Jiskani, B. Ullah, A.R. Qureshi, Comparative analysis of coal Miner's fatalities by fuzzy logic. J. Min. Environ. 12 (1), 77-87, (2021). https://doi.org/10.22044/JME.2020.9459.1856
14. DAWN. Pakistan's coal resources. https://www.dawn.com/news/371000/pakistans-coal-resources [Accessed on January 27, 2026].
15. M.J. Sajid, N.M Shahani, M.A. Ali, Calculating inter-sectoral carbon flows of a mining sector via hypothetical extraction method. J. Min. Environ. 10 (4), 853-867, (2019). https://doi.org/10.22044/jme.2019.8263.1701
16. Shah, S. A. H. (2018). Strategy for mineral sector development in Pakistan. Ministry of Planning, 1-24.
17. DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY. https://pubs.usgs.gov/of/1988/0251/report.pdf [accessed on 09/09/2022]
18. A.A. Qureshi, D.M. Kakar, M. Akram, N.U. Khattak, M. Tufail, K. Mehmood, K. Jamal, H.A. Khan, Radon concentrations in coal mines of Baluchistan, Pakistan. J. Environ. Radio. 48(2), 203-209, (2000).
19. Pakistan Mineral Development Corporation. http://www.pmdc.gov.pk/?p=SorRangeCollieries [accessed on 09/09/2022].
20. N.M. Shahani, Z. Wan, L. Guichen, F.I. Siddiqui, A.G. Pathan, P. Yang, S. Liu, Numerical analysis of top coal recovery ratio by using discrete element method. Pak. J. Engg. Appl. Sci. 25, 26-35, (2019).
21. N.M. Shahani, Z. Wan, X. Zheng, L. Guichen, C. Liu, F.I. Siddiqui, G. Bin, Numerical modeling of longwall top coal caving method at thar coalfield. J. Met. Mater. Miner. 30 (1), 57-72, (2020).