Determination of Optimum Coal Blending Ratio for Cement Industries of Pakistan

Hassan Raza Dars[a,*], Saleem Raza Chalgri[a], Shafi Muhammad Pathan[a], Muhammad Burhan Memon[a]

[a]*Department of Mining Engineering, Mehran University of Engineering & Technology, Jamshoro, 76062*

Abstract

Each spending day cost of gaseous petrol and heater oil is rising. Accordingly, In Pakistan coal is considering as a less expensive wellspring of power to defeat ongoing power emergency. Cement industries individually one of the top purchasers of coal from other countries, which diminishing the use of local Coal resources of Pakistan. One of the reasons why local coal isn't used in cement production is because of its poor quality. Having such a massive Coal resource in Pakistan, it is essential to make use of the local coal resources for economical development of local Coal market. General literatures and observes assumed and recommend that local coal can be blended with imported coals and mixing of coal has become an important method to reduce the cost of coals. The main purpose of this paper is to determine most favourable blending ratios as needed for long-term expansion by the cement industry. In this research, samples of imported coal gathered from Indonesia, Australia, Russia, & South Africa were obtained from Port Qasim Karachi. However, local Coal samples from Thar and Lakhra Coalfields. As per ASTM standards, Proximate, Ultimate and calorific value of imported, indigenous and blend Coal samples were find out. Finally, it is determined that Lakhra coal can be mixed up to 13% and 4%, with Russia coal and Indonesia coal respectively and resulted in saving foreign exchange up to 7% and 1.9%. Similarly, Thar coal can be blended up to 50% with Russian and Indonesia respectively and resulted in saving foreign exchange up to 50% and 30% to meet up the required of Cement Industries. This research may help to ensure the long-term viability of the local coal sector, which will ultimately aid Pakistan's cement industry.

Keywords: *Coal blending, Sustainable growth, Coal Utilization*.

1. Introduction

The primary purpose of coal is behind the modern transformation, at this point in continuous for a long-time. It is likewise, expected to assume a main part for a long time to come. A critical benefit of energy crisis has along these lines being the re-assessment of the capacity of coal in the world's financial system as a energy sources. Each spending days costs of flammable gas and heater fuels are ascending thus, Coals are considering as a less expensive wellspring of power to conquer the ongoing power-energy emergency in Pakistan [1]. Pakistan's coal resources are approximate to be 185 billion tonnes. [2]. Sindh Province has more than 175 billion tonnes of coal out of a total of 185 billion tons. [3]. Despite Pakistan's massive coal deposits, it has unable to reach a particular amount of utilisation. Due to rising demand in the building industry, many cement plants rely largely on imported coal. The cost of imported coal is rising every day, forcing cement manufacturers to substitute local coal for imported coal. [4]. Cement industries one of the more consumers of imported Coals, reducing the use of Pakistan's local Coal resources. One of the reasons why local coal isn't used in cement production is because of its poor quality. Coal blending is a well-known and dependable technology for cement production. [5]. Many cement plants throughout the world mix their low-quality coal with higher-quality coal to make it suitable for use in cement plants. Pakistan's cement industry is primarily reliant on imported coal, reducing the use of domestic resources. The justification given by the owners/managers for not utilising the indigenous resource is valid. One of the reasons why coal isn't used in the cement industry is because of its poor quality. Nonetheless, this provides an opportunity for researchers to focus on the proper usage of local coal resources. With such a large coal reserve in Pakistan, it is critical to make use of the local resource in order to ensure the long-term expansion of the local coal market. A large body of literature and best practises from several countries show that blending indigenous and imported coal is a good idea [6, 7]. Coal blending is practice of combination dissimilar kinds of coals to obtain products with desired properties [8, 9]. The use of local coal resources is a possible and inexpensive for discarding the recent

*Corresponding author. Tel.: +92 3423738346; fax: NA
E-mail address: hassanrazadars34@gmail.com

energy emergencies. [10]. On the other hand, the Pakistani rupee's (PKR) foreign exchange rate versus the US dollar (PKR/USD) has risen relatively unstable in current year. The development of most significant exchange rates and energy import are shown in (Figure1) [11,12].

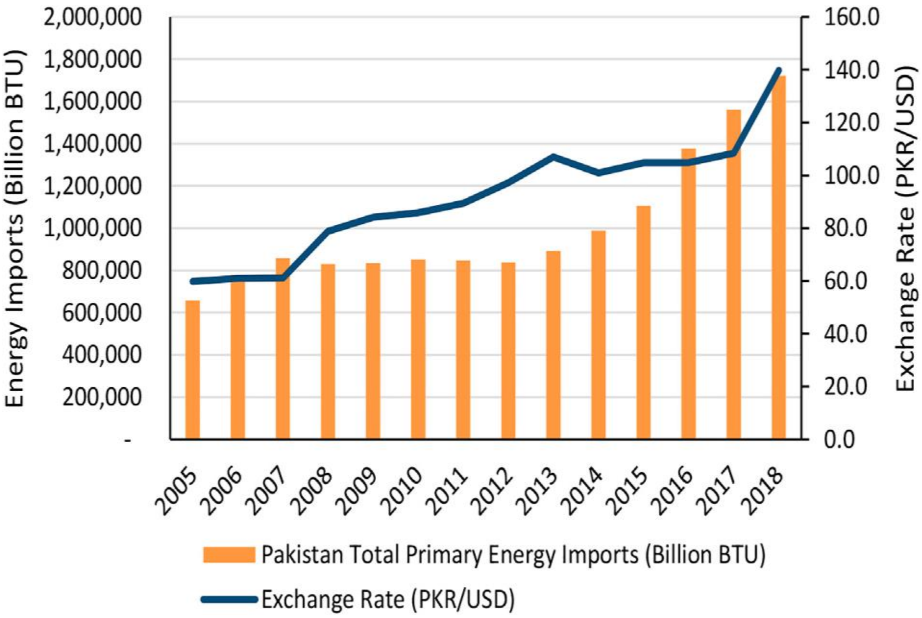

Fig. 1: Co-movement of substitute rates and energy imports (2005–2018)

1.1. Coal blending

It is the practice of blend coal once it has been extracted in order to obtain the desired quality for power plants, cement plants, and steel mills. The brilliance attributes that are mainly important in blending will be dissimilar from one mine to next. The main attributes of relevance in thermal coal are often calorific values, ash, volatiles matter, and total sulphur. The importance of coal for requirements is increasing as a result of the blending of indigenous and imported coal, and various mixing and blending methods have been recommended to reduce both long-term and short-term fluctuations in coal value.[13]. Coal blending is an important procedure to reduce the purchase of coal [14]. Coal blending is the process of combining several types of coal to create a blended coal sample with higher quality. The coal blending technique chosen for a certain site is determined by the conveniences available, the amount of coal to be mixed, and the mixing accuracy necessary. Physical blending in a research facility was used as the mixing approach for this study. The following is a simple example. [15].

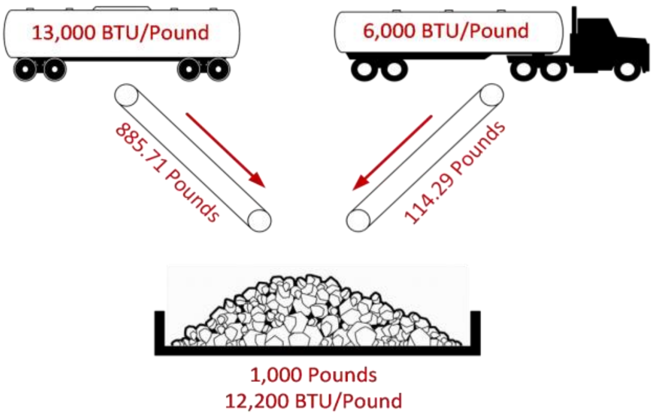

Fig. 2: Example on Coal Blending [13]

2. Material and Methods

2.1. Collection of Coal Samples

Coal samples were collected from six distinct regions, including Thar, Lakhra, Australia, Indonesia, South Africa, and Russia. Imported coal samples, on the other hand, were obtained from Karachi's Port-Qasim. To maintain their as-received state, these samples were stored in properly labelled plastic bags. The coal samples obtained from the fields weigh between 2 and 10 kilograms.

2.2. Coal Sample Preparation

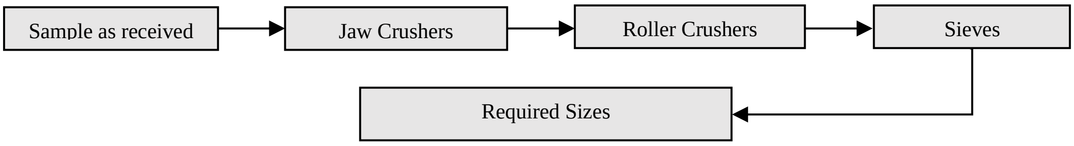

Fig. 3: Coal sample preparation steps

Collected coal samples were hammered and then put through a jaw and roll crusher, respectively. Coal samples were manufactured in accordance with ASTM standards in a variety of techniques as shown in Fig 2.1 [16]. Proximate, Ultimate, Hardgrove Grindability Index (HGI), and Calorific value tests were performed on coal samples. After crushing and grinding, the coal samples were sieved for 10 minutes to a size of 250m using an automatic sieve shaker. In order to retain the coal sample in natural qualities coal sample was placed in aluminum foils and keep them in Zip lock bag after sifting. According to ASTM standards, sample sizes for HGI were between 590 and 1190 sieves. After that, the coal samples are ready to be blended in various ratios.

2.3. Equipment for Coal Analysis

The equipment used for analyzing the coal samples were presented in my university, MUET Jamshoro. For Proximate analysis the LECO Thermogravimetric Analyzer (TGA-701) is consistent tool for determinate it. According to the ASTM standard each sample was ready to blend in different proportions then again analyzed in LECO TGA-701. This tool consists of a computer-based system and has a several sample furnace that allows up to 19 samples to be analyzed separately. For determine calorific value using the AC500 calorimeter calorimetric analyzer. For determination the percentage of sulfur, carbon, hydrogen, nitrogen and oxygen we are using ultimate analysis. But I need to identify the proportion of carbon and sulfur therefore I use SC832 analyzer [15–17]. Hard-Grove Grindability Index testing machine was used to know the percentage of Grindability index of coal sample.

2.3.1 Hardgrove Grindability Index (HGI) Test

To know the ease of pulverizing Coal samples HGI testing apparatus was used, initially clean-up the chambers of apparatus and to make 50g sample having grains range in among 590μ to 1190μ according to ASTM standards. Place a 50g sample weight in the bottom grinder part and an 8iron balls with a 1inch diameter in the bottom of the grinder part then tighten the bottom chamber to testing machine with screw. Now start machine after 60 revolutions the machine stop manually. Remove the sample from the bottom bowl grinding chamber and place it on a 75sievesize sieve, then sieve the sample for 10 minutes on a sieve shaker. After this, weigh the sample on a balance and subtract the weight from 50g. Grindability Index can be determined as follow [18,19].

$$HGI = [13 + (6.93W)] \quad (1)$$

Here, w is mass of minerals which pass throughout 75μsieve after grinding.

3. Result and Discussion

Blending of coal is efficient method of sustaining Pakistan's indigenous coals sector. The blended percentage shows that local coal can be mix with imported coal. Table 1 shows that more sulfur level in Lakhra coal is considerable, while the caloric value of Thar coal is low. However, South Africa and Australia have lower calorific values with higher ash coal as compared to Russia and Indonesia. Excel sheets were produced with SUM- PRODUCT method. When the ratios of the findings are changed, this table is a valuable approach. When we simply change the ratio, this will work automatically. If a value falls outside the range of the cement industry's requirements, it will be highlighted in color.

Table 1: Blending proportions model in Excel format for indigenous and

Seams and Waste	Thar	Lakhra	Australia	Indonesia	Russia	South Africa	Wt. Average	Required Range	Profit (%)
Ratio (grams)	4.5				5.5		10		
%	50	0	0	0	50	0	100%		
Tonnage	0.45	0	0	0	0.55	0	1		
M (%)	24.46	18.830	3.65	5.42	3.92	3.84	13.19	≤15	
Ash (%)	3.52	14.751	30.36	9.93	6.31	16.22	5.03	≤14	
V.M (%)	50.24	38.751	40.86	49.36	41.6	24.43	45.43		
F.C (%)	21.65	27.571	24.97	35.17	48.22	55.51	36.25		
T. S (%)	0.85	4.930	0.57	0.36	0.32	0.32	0.55	≤ 1	
Qnet (Btu/Lb)	9425.9	8627.9	9806.6	12502.5	12715	11036	11235	≥ 10799	
HGI	146	82.96	39.7	63.25	37.25	51.10	86	< 45 & > 55	
Cost/ton in PKR	5616	8776	18955	17198	15805	16496	11220	4585.05	40.86

3.1. Imported coal blended with Thar Coal

Thar coal was combined with imported coal in various proportions, and only a few of them produced optimal results, as indicated in the below figures.

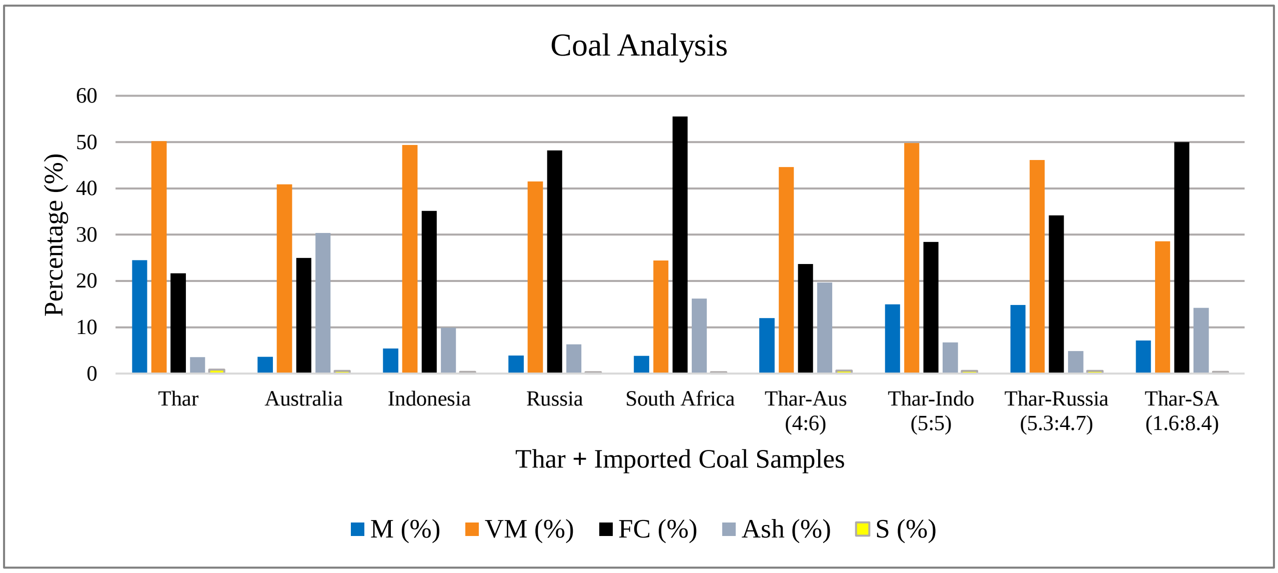

Fig. 4: Coal Analysis of Imported Coal with Thar coal

Fig. 4 shows the Moisture content, volatile matter, fixed carbon, and ash percentage are among the several analyses of coal samples. The Fig.4 also demonstrates that the Sulfur content of Thar and other imported coal samples was quite low.

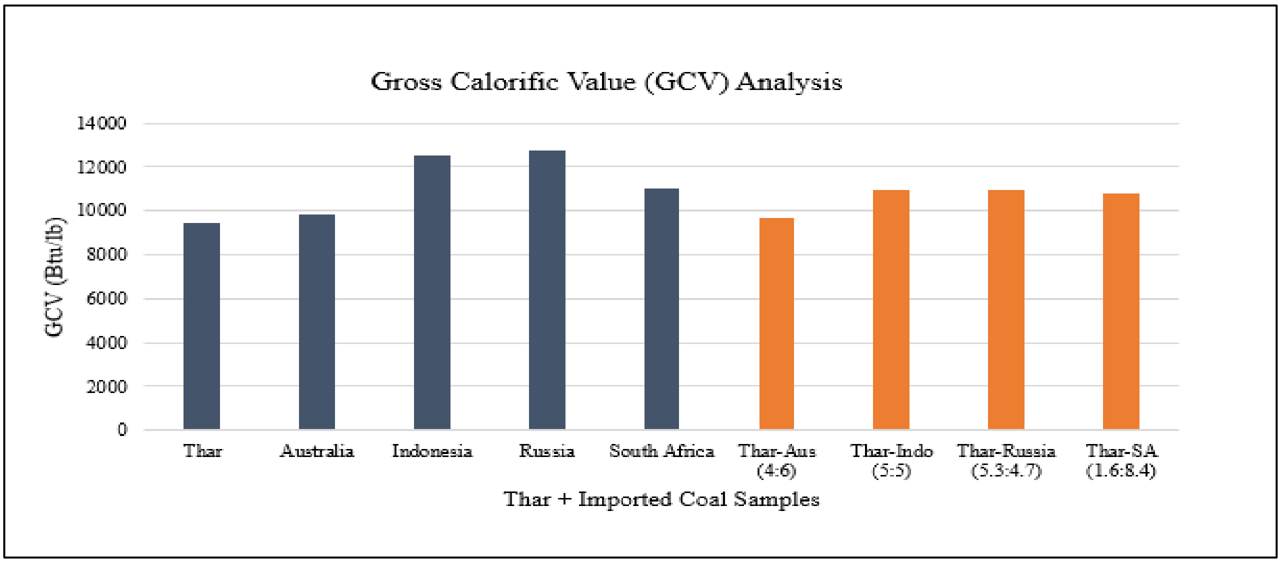

Fig. 5: GCV Analysis of Imported Coal with Thar coal

The gross calorific values for Thar and other imported coal samples are shown in Fig. 5. In Fig. 5, the gross calorific values of various blended ratios of Thar with imported coal have also been emphasized.

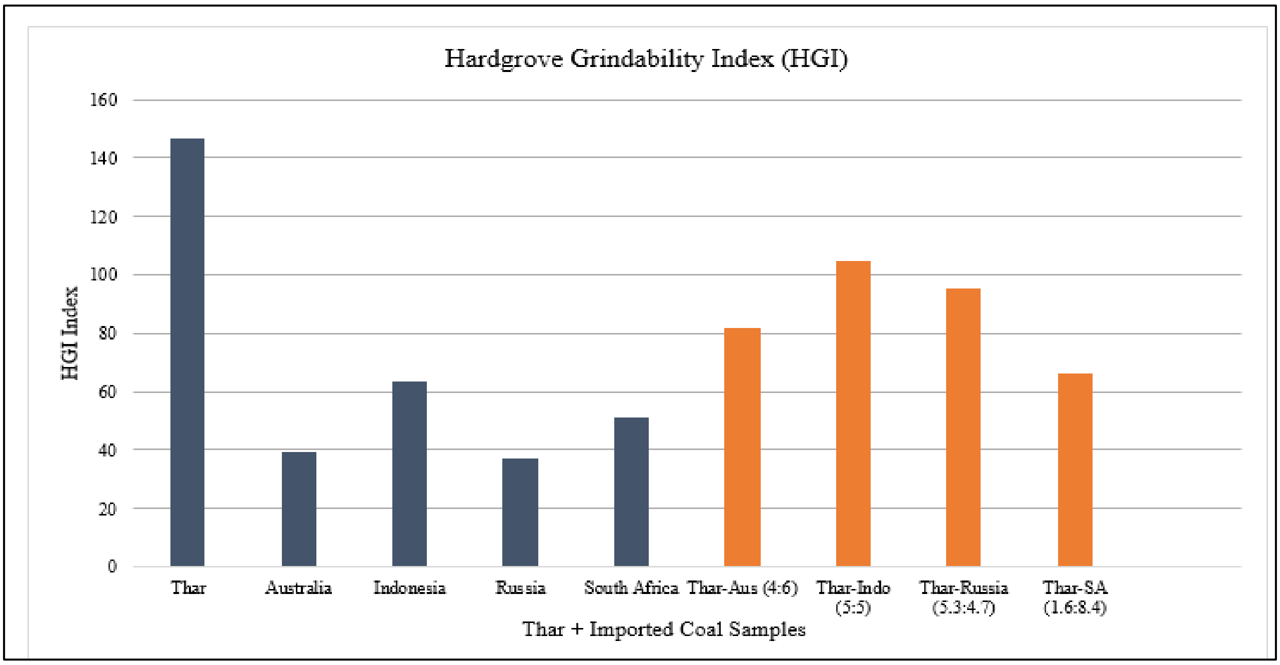

Fig. 6: HGI Analysis of Imported Coal with Thar coal

The Hardgrove grindability index is an important feature of coal that determines how easy it is to smash during pulverization. Because pulverized coal is utilized in the cement manufacturing process, Fig. 6 show various index values.

3.2. Imported coal blended with Lakhra Coal

Lakhra coal was mixed with imported coal in various quantities, and some of them produced optimum results, as shown in Fig. 7, 8 and 9 respectively. These findings point to improved outcomes and provide an opportunity for investments in the local coal sector.

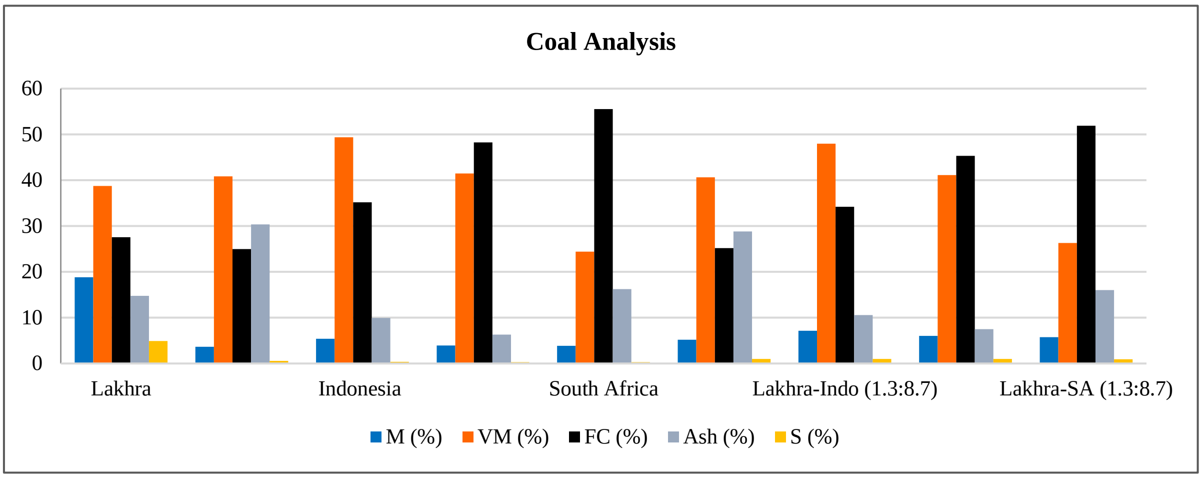

Fig. 7: Analysis of Imported Coal with Lakhra coal

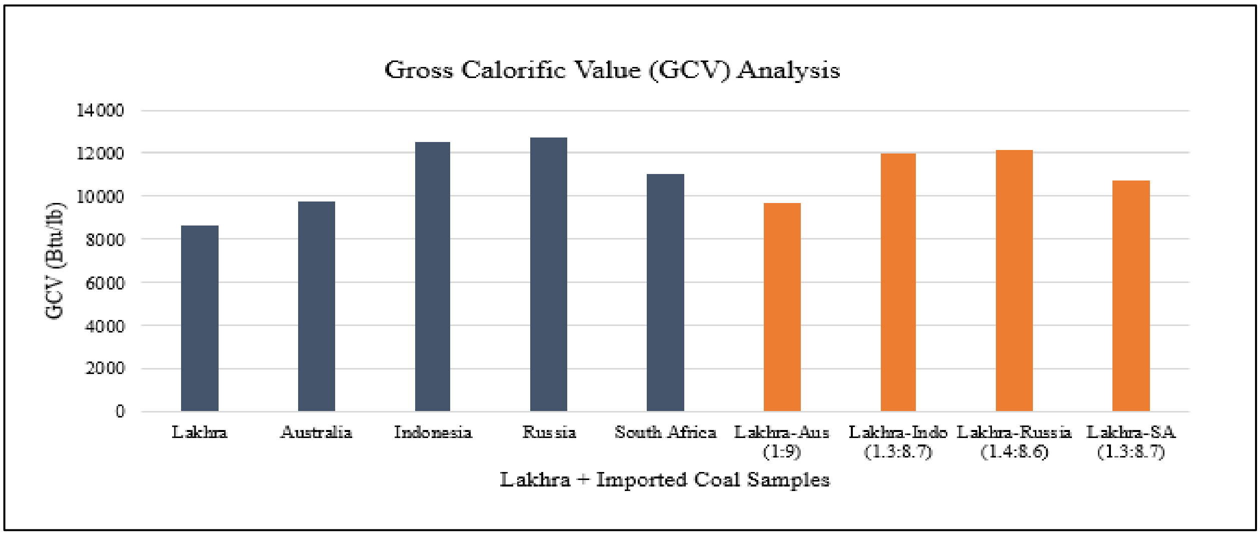

Fig. 8: GCV Analysis of Imported Coal with Lakhra

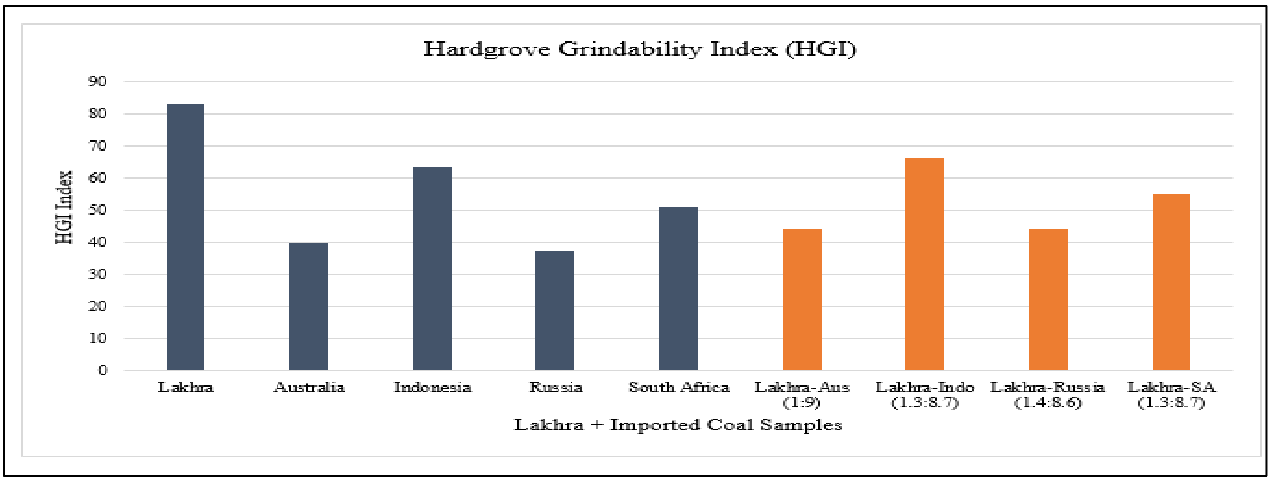

Fig. 9: HGI Analysis of Imported Coal with Lakhra

As shown in Table 2. The best appropriate coals are those from Russia and Indonesia, which may readily be blended with Thar and Lakhra coal after up-gradation. Blended ratio with Lakhra samples can save foreign exchange up to 7% and 1.9%., and blended ratios with Thar coal can save more than 50% in foreign exchange. Due to higher ash and lower calorific value, coal from Australia and South Africa cannot be blended, but it may be possible after up-gradation.

Table 2: Optimal blending ratios with maximum Saving % for cement

COAL	RATIO	AVG COST/TON	PROFIT/TON	SAVING %
Australia-Thar	Due to high ash and low calorific value, coal from Australia cannot be blended			
Indonesia-Thar	50:50	11408	5793	50.77
Russia-Thar	47:53	10401.96	5398.06	51.89
South Africa-Thar	Due to higher ash and lower calorific values, coal from South Africa cannot be blended			
Australia- Lakhra	Due to higher ash and lower calorific value, coal from Australia cannot be blended			
Indonesia- Lakhra-	87:13	16103.9	1095.124	6.80
Russia- Lakhra-	86: 14	14816.55	983.51	6.63
South Africa- Lakhra	Due to high ash and low calorific value, coal from South Africa cannot be blended			

4. Conclusions

The goal of this research is to determine the best blending ratios for the local cement industry's long-term growth. Evaluation of blended ratios has been achieved by using SUM-PRODUCT biased techniques in MS office excel and the research findings are quite useful in blending coal according to the specifications. . Finally it is determined that Lakhra coal can be mixed up to 13% and 4%, with Russia coal and Indonesia coal respectively and resulted in saving foreign exchange up to 7% and 1.9%. Likewise, Thar coal can be mixed up to 50% with Russian and Indonesia respectively and resulted in saving foreign exchange up to 50% and 30% to meet up the required of Cement Industries. This research may help to ensure the long-term viability of the local coal sector, which will ultimately aid Pakistan's cement industry.

Acknowledgements

Thank you to the following people for their expertise and assistance in all phases of our study, as well as for their aid in authoring the manuscript. Thanks to our department for providing coal testing facility, which the authors gratefully recognise. Thanks, are also extended to **Dr. Fahad Irfan Siddiqui,** who helped in arranging the imported coal used for blending in this study.

References

[1] I. M. Jiskani, W. H. Qazi, F. I. Siddiqui, and M. Y. Behan, "Blending of Local and Imported Coal for Cement Industries," *1st Int. Coal Conf.*, 2013.

[2] F. A. Malik and A. Aziz, "Use of coal in the energy mix of Pakistan," *32nd Annu. Int. Pittsburgh Coal Conf. Coal - Energy, Environ. Sustain. Dev. IPCC 2015*, 2015.

[3] A. Ahmad, M. H. Hakimi, and M. N. Chaudhry, "Geochemical and organic petrographic characteristics of low-rank coals from Thar coalfield in the Sindh Province, Pakistan," *Arab. J. Geosci.*, vol. 8, no. 7, pp. 5023–5038, 2015, doi: 10.1007/s12517-014-1524-6.

[4] I. M. Jiskani, F. I. Siddiqui, S. Memon, and M. Jokhio, "Coal Blending For Extended Utilization of Indigenous Coal Resources of Pakistan," *1st Natl. Conf. Metall. Mater.*, 2015.

[5] H. Hayashizaki, Y. Hayashi, Y. Kubota, K. Uebo, and S. Nomura, "Development of Coal Blending Technology for Improvement of Coke Quality," 2020.

[6] A. Iqbal, N. Ehsan, M. I. Khan, and I. Ashraf, "Analysis of dense medium beneficiation of Dandot coal for use in cement industry in pakistan," *J. Qual. Technol. Manag.*, vol. VII, no. I, pp. 115–130, 2011.

[7] R. Ibrahim, "Technology of cement production: issues and options for developing countries," *Massachusetts Inst. Technol.*, pp. 55–56, 1986.

[8] Y. M. Zhang, G. Z. Guo, L. La Zhang, and H. J. Wang, "Study on the industrial analysis and calorific value of coal blending," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 186, no. 6, 2018, doi: 10.1088/1755-1315/186/6/012030.

[9] G. Xi-jin, C. Ming, and W. Jia-wei, "Coal blending optimization of coal preparation production process based

on improved GA," *Procedia Earth Planet. Sci.*, vol. 1, no. 1, pp. 654–660, 2009, doi: 10.1016/j.proeps.2009.09.103.

[10] W. Ayoola, A. Oyetunji, and Y. D. Baba, "Proximate , Ultimate Analysis and Industrial Applications of Some Nigerian Coals," *ABUAD J. Eng. Res. Dev.*, vol. 2, no. 1, pp. 20–25, 2019, [Online]. Available: www.ajerd.abuad.edu.ng/.

[11] A. Saqib, T. Chan, A. Mikhaylov, and H. H. Lean, "Are the Responses of Sectoral Energy Imports Asymmetric to Exchange Rate Volatilities in Pakistan ? Evidence From Recent Foreign Exchange Regime," vol. 9, no. May, pp. 1–13, 2021, doi: 10.3389/fenrg.2021.614463.

[12] N. E. P. R. Authority, "National Electric Power Regulatory Authority Islamic Republic of Pakistan NEPRA/RIADG(Tariff)/TRF- 100/XWDISCOs/1080- 1082," 2021, [Online]. Available: https://nepra.org.pk/licensing/Licences/Generation/IPP-2002/Engro Powergen Thar/LAG-285 Modification-I Engro Powergen 14-10-2019.PDF.

[13] M. Yorukoglu, "Coal blending for power stations," *Madencilik*, vol. 56, no. 3, pp. 109–116, 2017.

[14] J. Xia, P. Peng, Z. Hua, P. Lu, and G. Chen, "Combinatorial optimization of pulverizers for blended-coal-fired power plant," *Proc. - Int. Conf. Comput. Distrib. Control Intell. Environ. Monit. CDCIEM 2011*, pp. 413–418, 2011, doi: 10.1109/CDCIEM.2011.323.

[15] Scott Hommel, "Example : Coal Drying," *Water*. 2019.

[16] J. G. Speight, "Handbook of Coal Analysis," *Handb. Coal Anal.*, pp. 1–227, 2005, doi: 10.1002/0471718513.

[17] M. S. Ullah, U. Zahid, and T. Masood, "Ultimate and Proximate Analysis of Coal Samples from Different Regions in Pakistan for their Future Utilization," *J. Heterocycl.*, no. November 2019, pp. 39–41, 2019, doi: 10.33805/2639-6734.107.

[18] U. Shafiq, "Proximate Analysis of Low and High Quality Pure Coal and their Blends from Pakistan," *Austin Chem. Eng.*, vol. 4, no. 1, 2017, doi: 10.26420/austinchemeng.2017.1048.

[19] A. Williams, M. Pourkashanian, J. M. Jones, and N. Skorupska, "Properties of Coal," *Combust. Gasif. Coal*, pp. 21–54, 2019, doi: 10.1201/9781315139746-2.

[20] N. M. Shahani, "An assessment of the effect of coal blending on Hardgrove grindability index," *Pet. Coal*, vol. 61, no. 2, pp. 269–276, 2019.

[21] A. S. Trimble and J. C. Hower, "Studies of the relationship between coal petrology and grinding properties," *Int. J. Coal Geol.*, vol. 54, no. 3–4, pp. 253–260, May 2003, doi: 10.1016/S0166-5162(03)00039-9.