Pakistan Institute of Development Economics

Knowledge Brief

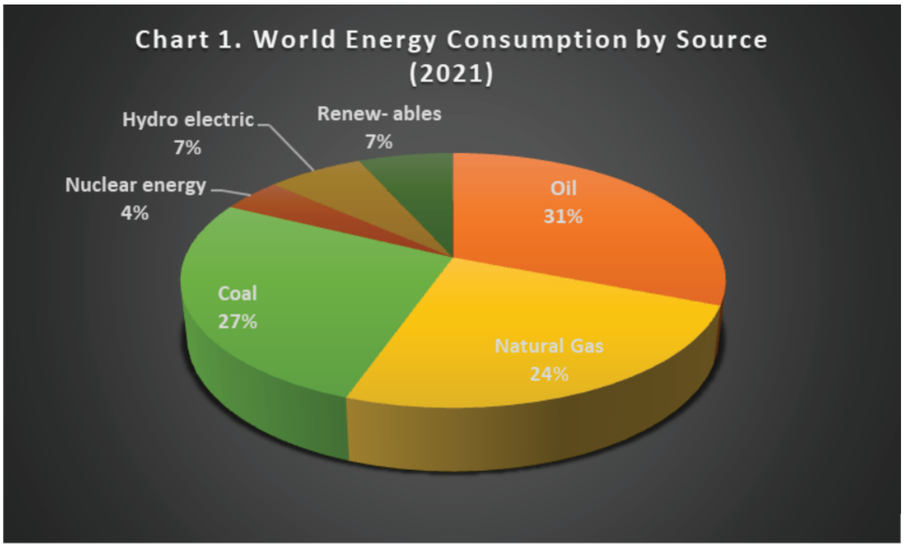
October 2023 No. 2023:103

LOCAL COAL FOR POWER GENERATION IN PAKISTAN

Afia Malik[1]
Senior Research Economist
Pakistan Institute of Development Economics, Islamabad.

PREFACE

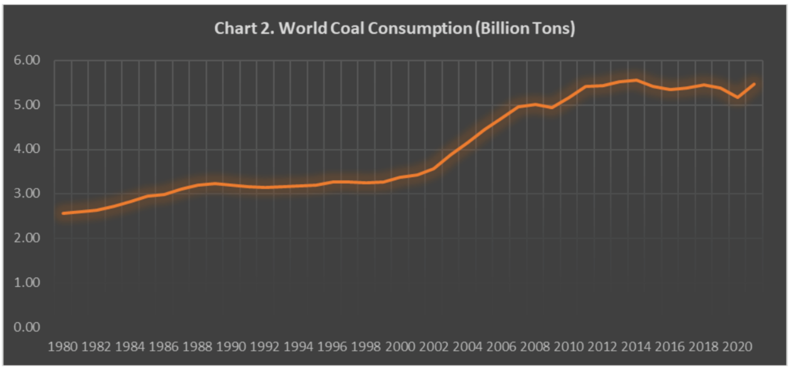
Coal contributes significantly to global energy supplies. In 2021, coal was the second-largest energy source consumed globally (Chart 1). Over the years, coal demand has increased substantially from 2.6 billion tons in 1980 to 5.5 billion tons in 2021 (Chart 2). Because of environmental concerns and the increasing trend towards renewables, its share declined in the United States and many European countries, decreasing global consumption in 2014 and onwards. But the trend reversed in 2020. It is because of the Russia-Ukraine war leading to the worldwide energy crisis that the demand for coal has increased.[2]



Source: BP Statistical Review 2022

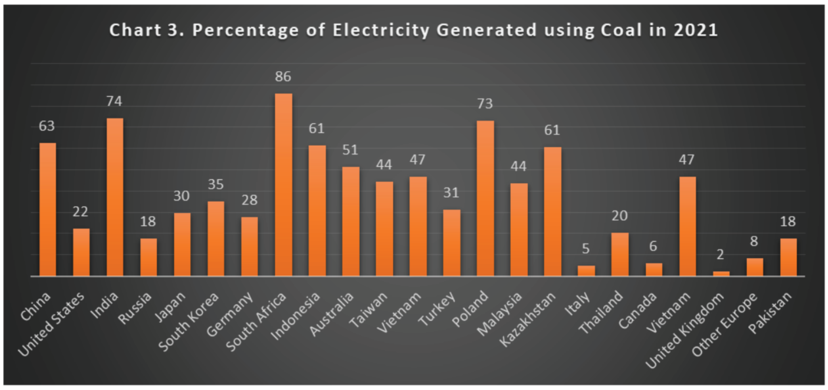
According to the International Energy Agency (IEA) forecast, coal demand is expected to exceed the previous coal demand record of 2014 in the next few years. The United States and many European countries are shifting back to coal as it is still one of the cheapest energy sources.

1. The author expresses gratitude to Dr. Nadeem ul Haque, Vice Chancellor, PIDE, and Engr. Tahir Basharat Cheema, Former MD, PEPCO, for providing valuable feedback on the initial draft and to Shafqat Abbas, Research Assistant, for support in information gathering.



Source: BP Statistical Review 2022

The primary coal-consuming sector is electricity generation. High natural gas prices have increased reliance on coal for generating power. Coal consumption in electricity generation is expected to grow by more than 2%.[3] If the gas prices continue to increase in 2023 or onwards, dependence on coal will remain, and demand will surge further.[4] Besides gas prices, coal prospects will depend on the transition speed towards renewable energy sources.[5]

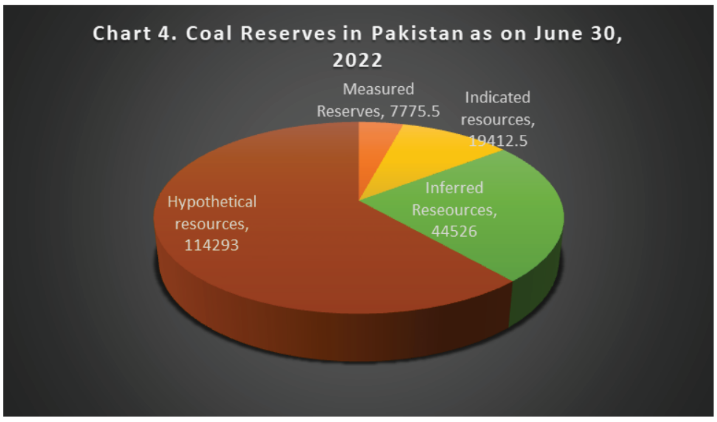


Source: BP Statistical Review, 2022

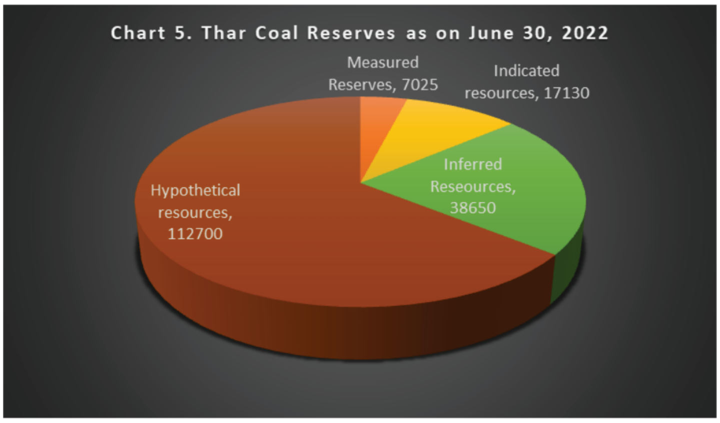
PAKISTAN COAL POTENTIAL

Pakistan has 186 billion tons of coal reserves, primarily located in the province of Sindh (Chart 4). Only Thar desert (10,000 sq. km) contains the world's 7th largest coal reserves of about 175 billion tons (Chart 5), equivalent to 50 billion tons of oil equivalent (more than Saudi Arabia and Iran's oil reserves) and 2000 trillion cubic feet of gas (68 times more than Pakistan's total gas reserves).

Thar Block-II alone contains 2 billion tons of lignite reserves, of which 1.57 billion tons are exploitable. This Thar Block-II can produce 5,000MW of electricity for 50 years, while the total Thar reserves can sustain 100,000MW for over two centuries.[6] Most of the coal in Pakistan is lignite (with more moisture content, up to 50%).



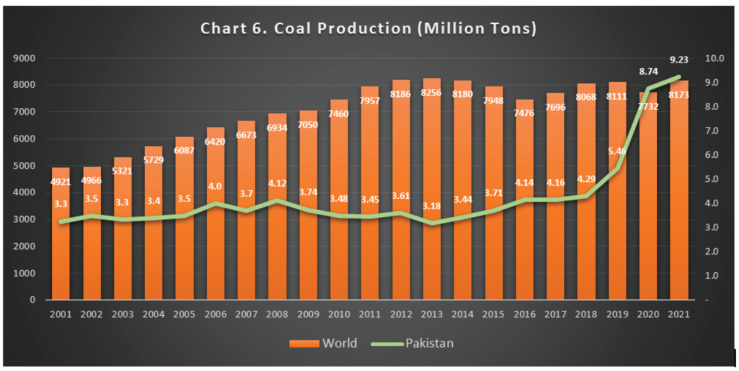
Source: Pakistan Energy Yearbook, 2022



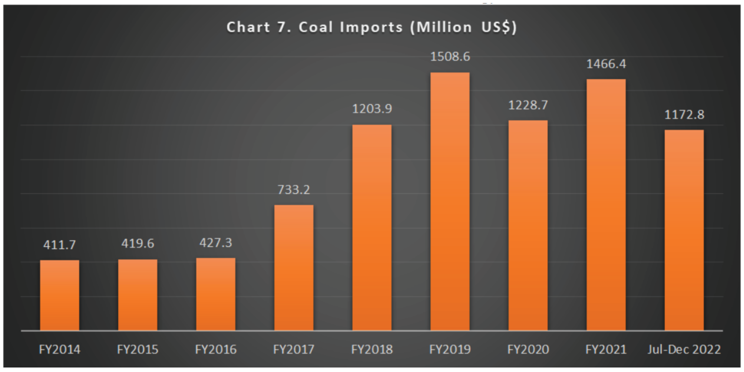
Source: Pakistan Energy Yearbook, 2022

PAKISTAN COAL CONSUMPTION, PRODUCTION, AND QUALITY

Globally, 8,172.6 million tons (Mt) of coal was produced in 2021. The top five coal producers were China,[7] India, Indonesia, the USA, and Australia, with a share of 50%, 10%, 8%, 7%, and 6%, respectively. Coal mining is critical to many economies,[8] enabling them to grow stronger and tackle the dual challenges of poverty and development (PACRA, 2020).



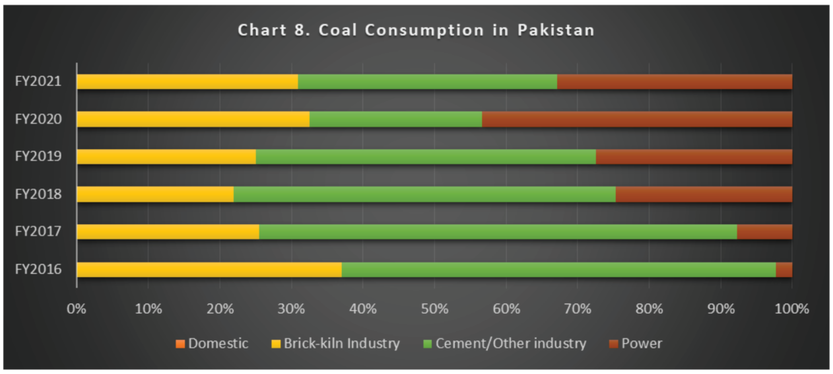
Source: BP Statistical Review 2022 and Pakistan Energy Yearbook 2022



Source: State Bank of Pakistan, 2023

Despite having colossal coal potential, coal production in 2021 was only 0.1% of the coal produced globally. About 67% of the country's total coal consumed (28.1 million tons) in 2021 was imported. Pakistan spent about US$ 1.5 billion on coal imports in FY2021 (Chart 7).[9] An import-dependent energy policy is unsustainable for Pakistan, especially given its limited foreign exchange reserves and in the global context. The global economy has been experiencing a commodity super-cycle due to many factors, including the Russia-Ukraine conflict and COVID-related logistical issues leading to rising prices and disruptions in global supply chains due to the Ukraine-Russia War (Sheikh, 2022).

Even after an 8% growth in Pakistan's coal consumption in the four decades, its share in world consumption is 0.4%. Power generation, the cement industry, and brick kilns are major coal consumers in the country (Chart 8). Imported coal is used in coal fire power plants and the cement industry, about 50% each (Ali, 2022). The main argument for not using local coal is its quality, mostly lignite with more moisture content (Table 1 and Table 2). However, it is also a fact that lignite quality produced in Pakistani fields is better than coal produced and used for electricity generation in India (Table 3). The second primary concern is the expense of transporting Thar coal to the power plants, e.g., Sahiwal and Port Qasim due to the absence of a railway connection with the Thar coal site.



Source: Pakistan Energy Yearbook, 2022

Out of total reserves at Thar amounting to 175,506 million tons, 16% are divided into twelve blocks with an area covering 1,121 sq km. Blocking of the remaining 84% of reserves still needs to be done. Phase I of Block II was commissioned in July 2019.

Table 1. Thar Coal Qualities for Blocks I to XII

Block	Area (km^2)	Total Reserves (billion ton)	Moisture (%)	Ash (%)	Vol. Matter (%)	Sulphur (%)	Heating Value (As Received) (Btu/lb)	Fixed Carbon (%)
I	122.0	3.56	43.13	6.53	30.11	0.92	6,398	20.11
II	79.6	2.24	47.89	7.37	25.15	1.12	5,008	19.68
III-A	99.5	2.00	45.41	6.14	28.51	1.12	6,268	19.56
III-B	76.8	1.45	47.72	9.30	25.49	1.15	4,808	16.79
IV	82.0	2.47	43.24	6.56	29.04	1.20	5,971	21.13
V	63.5	1.39	46.82	8.92	30.24	1.20	5,682	13.26
VI	66.1	1.65	46.80	5.89	29.34	0.90	5,727	16.6
VII	100.0	2.17	48.27	8.03	25.30	1.16	5,440	25.30
VIII	100.0	3.03	49.57	7.78	24.32	1.44	5,302	18.10
IX	100.0	2.86	48.60	5.92	29.03	0.96	5,561	15.73
X	100.0	2.87	48.99	6.35	30.79	1.17	4,840	13.54
XI	101.0	1.61	49.97	8.07	24.16	1.61	5,228	17.26
XII	100.0	2.34	50.82	5.71	25.00	1.11	5,459	17.26

Source: JICA (2013)

Table 2. Coal Quality of Coalfields in Pakistan

Province / Coal Field	Coal Quality Proximate Analysis (in percent)					Rank ASTM Classification	Heating Value (mmmf) Btu/lb	Heating Value (mmmf) Kcal/kg	Average Annual Production 2000-2001 (tonnes)
	Moisture	Volatile Matter	Fixed Carbon	Ash	Total Sulphur				
SINDH									
Lakhra	9.7 - 38.1	18.3 - 38.6	9.8 - 38.2	4.3 - 49	1.2 - 14.8	LigB to SubC	5,503 - 9,158	3,057 - 5,088	1,112,406
Sonda-Thatta	22.6 - 48.0	16.1 - 36.9	8.9 - 31.6	2.7 - 52.0	0.2 - 15.0	SubC to hvBb	8,878 - 13,555	4,932 - 7,531	-
Jherruk						SubC to hvCb	8,800 - 12,846	4,889 - 7,137	-
Ongar	9.0 - 39.5	20.0 - 44.2	15.0 - 58.8	5.0 - 39.0	0.4 - 7.7	LigB to SubA	5,219 - 11,172	2,899 - 6,207	-
Indus East						LigA to SubC	7,782 - 8,660	4,323 - 4,811	-
Meting-Jhumpir	26.6 - 36.6	25.2 - 34.0	24.1 - 32.2	8.2 - 16.8	2.9 - 5.1	LigA to SubC	7,734 - 8,612	4,297 - 4,784	-
Badin*	15.4 - 29.8	29.8 - 39.8	31.0 - 36.3	8.2 - 14.6	3.4 - 7.4		6,740 - 11,100	3,744 - 6,167	-
Thar Coal	29.6 - 55.5	23.1 - 36.6	14.2 - 34.0	2.9 - 11.5	0.4 - 2.9	LigB to SubA	6,244 - 11,045	3,469 - 6,136	-
BALOCHISTAN									
Barkhan-Chamalang	1.1 - 2.9	24.9 - 43.5	19.4 - 47.1	9.1 - 36.5	3.0 - 8.5	hvCb to hvAb	12,500 - 14,357	6,944 - 7,976	NA
Duki	3.5 - 11.5	32.0 - 50.0	28.0 - 42.0	5.0 - 38.0	4.0 - 6.0	SubB to hvAb	10,131 - 14,164	5,628 - 7,869	278,518
Mach Abegum	7.1 - 12.0	34.2 - 43.0	32.4 - 41.5	9.6 - 20.3	3.2 - 7.4	SubA to hvCb	11,110 - 12,937	6,172 - 7,187	317,004
Sor Range - Deghari	3.9 - 18.9	20.7 - 37.5	41.0 - 50.8	4.9 - 17.2	0.6 - 5.5	SubA to hvBb	11,245 - 13,900	6,247 - 7,722	279,564
Pir Ismail Ziarat	6.3 - 13.2	34.6 - 41.0	19.3 - 42.5	10.3 - 37.5	3.2 - 7.4	SubA to hvCb	10,786 - 11,996	5,992 - 6,664	384,108
Khost-Shahrig-Harnai	1.7 - 11.2	9.3 - 45.3	25.5 - 43.8	9.3 - 34.0	3.5 - 9.55	SubB to hvAb	9,637 - 15,499	5,354 - 8,611	227,784
PUNJAB									
Makarwal	2.8 - 6.0	31.5 - 48.1	34.9 - 44.9	6.4 - 30 8	2.8 - 6.3	SubA to hvAb	10,688 - 14,029	5,938 - 7,794	47,928
Salt Range	3 2 - 10 8	21.5 - 38.8	25.7 - 44.8	12.3 - 44.2	2.6 - 10.7	SubC to hvAb	9,471 - 15,801	5,262 - 8,778	221,964
NWFP									
Hangu/Orakzai	0 2 - 2.5	16.2 - 33.4	21.8 - 49.8	5.3 - 43.3	1.5 - 9.5	SubA to hvAb	10,500 - 14,149	5,833 - 7,861	77,000
Cherat/Gulla Khel	0.1 - 7.1	14.0 - 31.2	37.0 - 76.9	6.1 - 39.0	1.1 - 3.5	SubC to hvAb	9,388 - 14,171	5,216 - 7,873	36,006
Azad Kashimir									
Kotli	0 2 - 6.0	5.1 - 32.0	26.3 - 69.5	3.3 - 50.0	0.3 - 4.8	LigA to hvCB	7,336 - 12,338	4,076 - 6,854	

hvAb =high volatile A bituminous coal   ASTM =American Society For Testing and Materials
hvBb =high volatile B bituminous coal   To convert Btu to Kcal/Kg multiply by 0.556.
hvCb =high volatile C bituminous coal   To convert Kcal /Kg to Btu/lb multiply by 1.798

Source: Geological Survey of Pakistan (June 30, 2011), Badin*: Sindh Coal & Energy Department, GoS 2010

Note: Table is cited from JICA (2013)

Table 3. Thar Coal Comparison with Other Mines

	Heating Value (Net) (Kcal/ kg)	Sulfur (%)	Ash	Moisture	Stripping Ratio (m^3/t)
	Higher is better	Lower is better	Lower is better	Lower is better	Lower is better
Thar Block II	2770	1.07	7.8	47.46	6.12
Gujarat, India	2600 - 3000	3.4 - 5.9	9 – 12	38.40	9 – 14
Hambach, Germany	1911- 2747	0.2 – 0.4	2 – 5	48.52	6.3
Maritza East – Bulgaria	1550	4.5	19-35	54	1.7

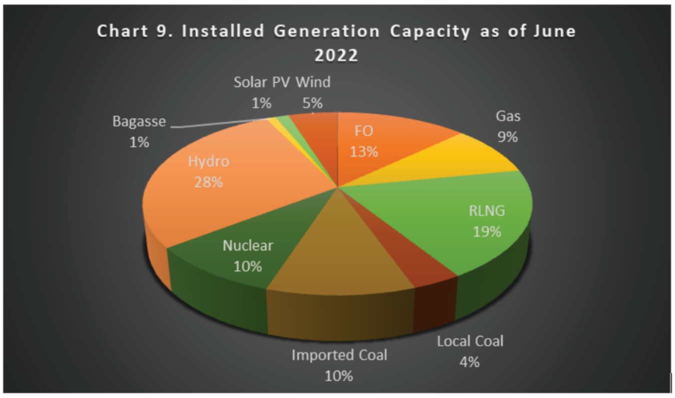
Source: PPIB

COAL-BASED POWER GENERATION IN PAKISTAN

In the electricity fuel mix of Pakistan in FY2021, coal share (both local and imported) was 18%. Much lower than many developed and developing countries (Chart 3). This share was reduced to 14% in FY 2022 (Chart 9). Because of the global coal price surge and shortage of foreign reserves, companies could not import coal.

Pakistan is seeking to expand the share of domestic coal in the electricity fuel mix. The objective is to save foreign exchange on import-base electricity generation, which stands at about 30% as of June 30, 2022. The government has developed policies and frameworks to enhance the local share. The share of local coal in the fuel mix for FY2024 is projected to be over 16%.[10] Unfortunately, due to the long-term agreements with commissioned and committed energy projects, the share of imported coal and RLNG would remain at 7% and 12% by FY2031 (Chart 10). It is challenging to convince power projects already commissioned on imported coal to switch to local coal.[11]

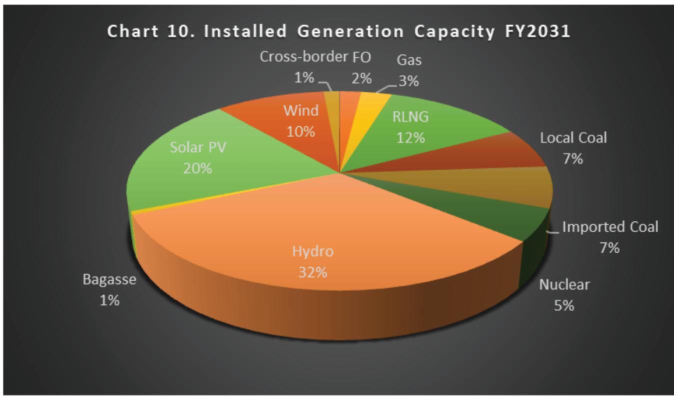
Under the Power Generation Policy 2015, preference was given to RLNG and coal and not to reducing reliance on imported fuels. As a result, the new projects under this policy are becoming increasingly dependent on imported fuels. Utilizing local resources has always been a priority in our planning strategies. Regrettably, we have not seen the desired level of effective implementation.



Source: IGCEP 2023-31

As of June 30, 2022, the installed capacity based on imported coal was 4620MW, higher than the capacity based on domestic coal (3600MW). Domestic coal-based power generation capacity has been delayed for more than three decades due to a lack of infrastructure, insufficient financing, and the absence of modern coal mining technical expertise (cited from Sheikh, 2022).

Thar coal reserves were discovered in 1992 by the Geological Survey of Pakistan. Nevertheless, this cheap potential was not realized given our lack of long-term vision and planning capacity for two decades. The focus remained on imported fuels. The environment was not the reason for not realizing this vast potential, but financing the mega project was. It was in 2012 when Sindh Engro Coal Mining Company (SECMC) launched coal mining as a joint venture between the Government of Sindh and Engro.[12]



Source: IGCEP 2023-31

Under the 2015 generation policy, several coal-fired power plants entered the system. Though high returns on equity were offered to locally sourced power plants (Table 4), low global coal prices at that time and slow progress in Thar mining failed to attract much investment in plants using Thar coal. High moisture content in the local coal was regarded as not suitable for the technology to be used. Plus, given the great distance of the coal reserves from load centers, the government also promoted importing coal. At that time, policymakers assumed coal-based generation was the best option to scale up power generation in the country (Bhandary & Gallagher, 2022).

Despite the importance of the power plant's proximity to the mine, it was not given much consideration in Pakistan. Instead, the preference was given to imported coal without realizing it would increase the burden on foreign exchange reserves.

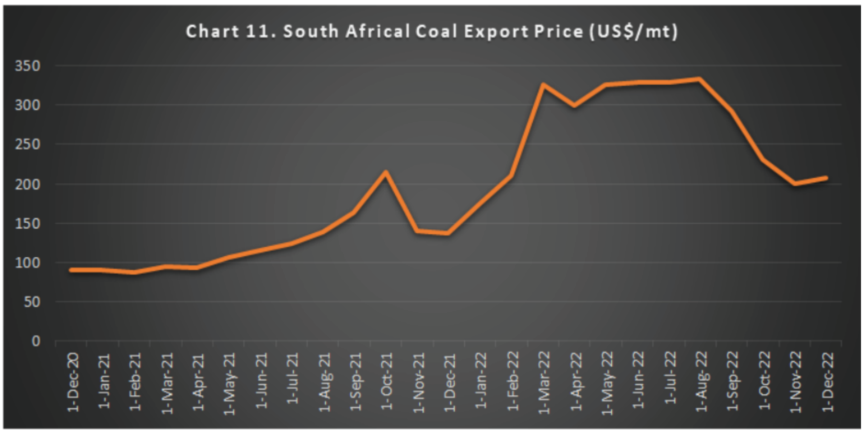
The unit cost of imported coal-fired power plants is much higher than local coal-fired power plants (Table 4). Coal for power generation is mainly imported from South Africa and Indonesia. Coal prices have inflated tremendously. The global coal price index reached 483.84 index points in October 2022.[13] It was 119.18 index points in January 2020. Although figures decreased compared to the previous month, net coal prices have significantly increased over the past two years. For instance, the South African coal export price increased from US$ 90.63 per metric ton in December 2020 to US$ 332.84 per ton in August 2022 (Chart 11). Consequently, the per unit cost of electricity generated from imported coal increased from Rs. 10.17/kWh to Rs. 29.12/kWh last year. As a result, these plants became lower on the Economic Merit Order (EMO), putting pressure on the capacity payment part of the tariff. In comparison, the per unit cost of electricity generated from Thar Coal during FY 2022 was around Rs. 7 / kWh to Rs. 9/kWh (NEPRA, 2022).

Table 4. Coal-based Installed Capacity as of June 30, 2022

Plants_ Commissioned	Coal Type	Capacity MW	RoE %	Fixed O&M $/KW/Year	Variable O&M $/MWh	Fuel Cost $/GJ	Heat Rate GJ/MWh	Unit Cost $/MWh	Unit Cost Rs/KWh
Lucky*	Imported	660	27.2	25.39	2.94	0.95	9.23	11.71	2.08
Engro Thar	Local	660	30.65	338.96	6.21	1.47	9.66	20.37	3.62
Port Qasim	Imported	1320	27.2	28.07	1.24	14.15	9.01	128.71	22.90
Sahiwal	Imported	1320	27.2	24.87	1.22	17.50	8.51	150.09	26.71
China HUBCO	Imported	1320	27.2	26.64	3.02	17.39	8.95	158.73	28.25
Plants_ Committed	Coal Type	Capacity MW		Fixed O&M $/KW/Year	Variable O&M $/MWh	Fuel Cost $/GJ	Heat Rate GJ/MWh	Unit Cost $/MWh	Unit Cost Rs/KWh
Thar I	Local	1320	34.49	97.21	6.20	1.47	9.23	19.72	3.51
Thal Nova	Local	330	30.65	98.97	6.20	1.47	9.73	20.45	3.64
Thar Tel	Local	330	30.65	98.97	6.20	1.47	9.73	20.45	3.64
Gwadar	Imported	300	17	33.77	1.15	2.80	9.66	28.21	5.02
Jamshoro Coal U1	Imported	660	---	5.06	2.85	6.17	8.71	56.59	10.07

Source: IGCEP 2022-31 and NEPRA

* Lucky Electric Power's 660MW is ultra-supercritical coal-fired plant started commercial operations on 21 March 2022. It is designed to burn a wide range of coal from diverse sources, including domestic coal.



Source: https://ycharts.com/indicators/south_african_coal_export_price#:~:text=Basic%20Info,50.50%25%20from%20one%20year%20ago.

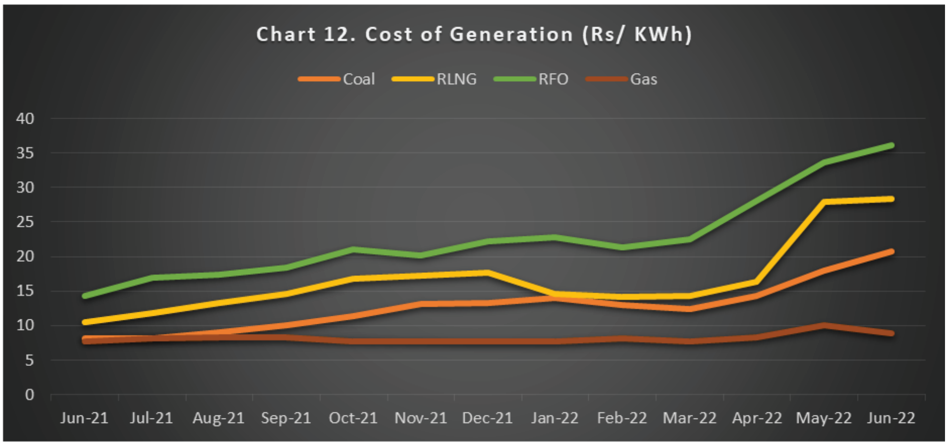
Pakistan is still in the initial stages of developing Thar coal resources. The costs will be reduced even more with expansion and reaching the optimum level. As Rizvi (2021) mentioned, coal mining, like other mineral resources, is a 'game of economies of scale' globally.

Compared to other fuels, coal-based generation costs in Pakistan remained low compared to RLNG and RFO (Chart 12) because of cheap domestic coal share. Coal-fired electricity tariff is lower than other fuels even though the upfront tariff determined by NEPRA was more than the average tariff levied in most South Asian Countries at that time (Abbasi, 2014). If the upfront tariff had been determined per the international rates, coal-based generation costs would have been lower.

Natural gas-based cost of generation is the lowest among fossil fuels. Nevertheless, its resources are depleting rapidly. Therefore, it is not dependable. Increasing the share of Thar coal via replacing/ substituting it with a portion or all of the imported coal can reduce the average cost of electricity generation and save foreign exchange reserves.

Despite being the cheapest, renewables in Pakistan cannot be adopted on a large scale. Pakistan is not ready yet. First, for solar PV, Pakistan heavily relies on imports from China for its equipment, and its domestic industry has yet to develop. Secondly, other costs, e.g., seasonality and lack of storage and transmission infrastructure, have made this a relatively expensive choice for Pakistan.[14]

Local coal is Pakistan's reliable and inexpensive fossil fuel option for sustaining energy supply, especially given the country's growing population, increasing energy demand, and volatile global oil and LNG prices; however, up to a specific acceptable limit (Cheema et al., 2022).



Source: NEPRA State of Industry Reports (2021 & 2022)

BLENDING IMPORTED COAL WITH LOCAL COAL

Due to the rise in imported coal prices, the power plants have been exploring alternate cheaper coal sources on the advice of the GOP. Imports from Afghanistan are allowed provided its MMBTU price is lower than the international coal prices, and payments are permitted in Pakistan Rupees. As stated in the NEPRA State of Industry Report (2022), the existing capacity of Afghanistan coal is insufficient, and there is no published price index for Afghanistan coal, which is liquid, transparent, and reflective of the market. Therefore, the best would be to convert the existing capacity of imported coal power plants under long-term agreements of 30 years to Thar coal.

In Pakistan's coal power plants (Table 4), the Pulverized Coal Combustion (PCC)[15] System is used: subcritical (SUBC) and supercritical (SC) types. The SC boiler is used in the Sahiwal, Port Qasim, and China HUBCO power plants. According to the third modification in its license, Lucky Power Plant has upgraded its technology to ultra-supercritical (USC). These plants are designed to burn different coal types. The SUBC boilers are used in the remaining power plants. The Gwadar power plant has yet to start its operations. However, under the pressure of the Chinese government, the government is forced to allow imported coal. All other SUBC plants under operation in the country are using Thar coal.

Since the 3960 MW installed capacity is based on imported coal, a certain percentage of the blend can reduce the import burden significantly. Literature suggests that it is possible to replace a certain percentage of bituminous coal (imported in the case of Pakistan) with lignite coal (Thar coal) without any plant modification.

Box1. Appropriate Blending Ratio

SC coal-fired power plants are designed to burn 100% sub-bituminous coal with vertical and roller-type pulverizers. Based on global experiences in boilers firing sub-bituminous coals, a moisture content of 30% is the maximum limit for such boilers to avoid any damage to the boiler.

In SC plants in Pakistan, Thar coal can be mixed up to 20%. Mixing 20% Thar coal and 80% sub-bituminous coal in weight, the moisture content of uniformly mixed coals is calculated as follows:
Moisture in normal design basis: (22.4 x 80+ 47.6 x 20)/100= 27.44%
Taking account of a deviation of 10% on moisture contents, 20% would be an upper limit for the mixing lignite produced in Thar with the imported sub-bituminous.

Source: (JICA, 2016)

By replacing 20% of the imported coal used (Box 1) in power plants, Pakistan can save over US$ 147 million of the amount used for coal imports in 2021 (i.e., US$ 1466.4 million).

It is enormous, given the pressures on our foreign reserves. Jamshoro Coal Power Plant is planning to employ SC new boiler(s) to use imported sub-bituminous coal blended with local coal in a ratio of 80:20 as its fuel (ADB, 2022).

Coal blending is practiced worldwide to avoid disruption due to transportation problems or fuel costs. Globally, coal of various types is blended at different points, including the mine, preparation plant, trans-shipment point, plant site, or even at the boiler. The method selected depends upon the site conditions, the level of blending required, the quantity to be stored and mixed, the accuracy required, and the end use of the blended coal. Large power plants treating coal in bulk prefer a mechanized stacking method (Sloss, 2014).

16

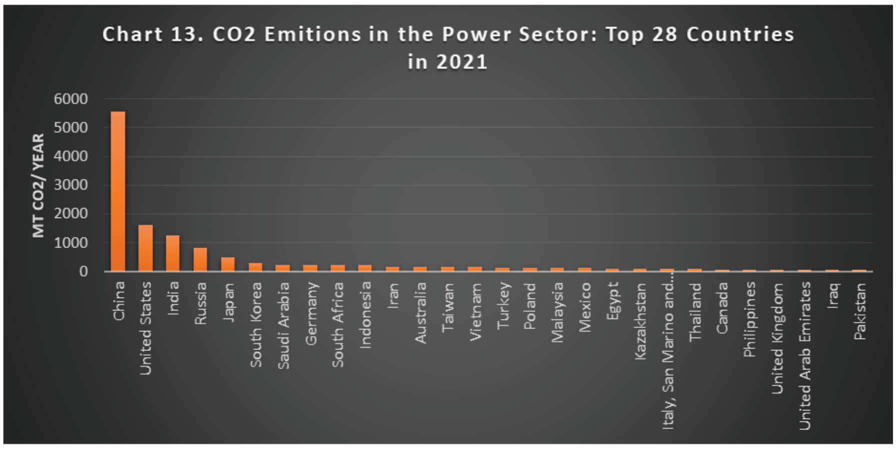
In PCC plants, the sub-bituminous (imported) coal is pulverized to a powder form, which is later fired from sideways. It does not require pre-drying as the coal used (sub-bituminous) is usually dry. With technology, it is possible to pulverize lignite coal. Thar coal's pre-drying process can be done through solar energy; Thar has plenty of sunshine. It can be dried at both mines and power plants. Exhaust steam is generally used in a reverse cycle for extra drying. This has already been done in Germany. Lucky Power reportedly uses almost the same approach in burning imported lignite and eventually plans to use local lignite (Ali, 2022).

COAL AND ENVIRONMENT

Despite being the cheapest fossil fuel, coal is the most environmentally detrimental energy source and is considered a significant contributor to climate change. The Paris Agreement calls for eliminating coal use in the power sector by 2050 (Sheikh, 2022). Nevertheless, its use is increasing globally.

Pakistan's power sector contribution to global power sector emissions is hardly 0.4% compared to over 38% by China, 11% by the US, 9% by India, and 6% by Russia in 2021. Still, as per the Global Climate Index 2021, Pakistan is the 8th most vulnerable country to climate change. The technology used in coal-fired power plants is vital from an environmental perspective.

Subcritical power plants (SUBC) achieve thermal efficiency in the range between 34% and 40% (based on coal heating value), with a global average efficiency of around 36%, whereas supercritical power plants (SC) reach efficiencies between 42% and 45%. Ultra-supercritical power plants (USC) employ advanced metal alloys to withstand extreme steam conditions and achieve even higher efficiencies. This is due to the elevated steam conditions: superheat and reheat steam temperatures of 600/620oC and steam pressures of up to 275 bar. Advanced ultra-supercritical power plants (A-USC) are expected to enter operation in the next decade, which will approach 50% net electricity generation efficiency with advanced metal alloys capable of withstanding steam temperatures and pressures over 700oC and 350 bar (Tramošljika et al., 2021).



Source: https://edgar.jrc.ec.europa.eu/report_2022

In Pakistan, SC boilers are used in more than half of coal-fired capacity (4680 MW: commissioned and committed), with a minimum net thermal efficiency of 39% and a maximum of 40.5%.[17] SUBC boilers are used in the remaining power plants of Engro, Thar I, Thal Nova, Thar Tel and Gwadar with a minimum net thermal efficiency of 37% and a maximum of 38.5% (as per the license issued by NEPRA).

SUBCs are less efficient, and countries are dumping these to reduce carbon footprints. Several countries across the world have moved towards USC (Box 2). Besides granting high upfront tariffs on coal-fired power plants, NEPRA failed to regulate heat rate, measuring the efficiency of power plants to convert a fuel (coal) into heat and electricity (Abbasi, 2014).

Higher efficiency translates into less coal consumption to generate a single unit of electricity while reducing CO2 emissions, mercury, and local air pollutants, releasing less local air pollutants, and leaving a smaller environmental footprint. Above all, it means lower consumer tariffs (Abbasi, 2014). Additionally, SC and USC require less water to generate electricity (per MW) than non-SC power stations (Alkon et al., 2019; Abbasi, 2014). However, generation capacity is the most crucial driver of cooling water demand magnitude.

Under efficiency-linked improvements in coal-power technology, SC and USC coal power generation technologies operate at higher temperatures and pressures than conventional (SUBC) pulverized coal combustion (PCC) plants, achieving high efficiencies. SC technology is considered clean coal technology as CO_2 emissions are less than for older plants. Therefore, the environmental impact of such technologies would be less.[18]

Replacing an old SUBC power plant with SC parallels a 10% efficiency gain and a CO_2 emission reduction of more than 20%. For example, a conventional SUBC generates electricity at 36% thermal efficiency with around 1000 kgCO2/MWh emissions. In comparison, a USC unit with 46% thermal efficiency generates 28% (0.46/0.36 = 1.28) more electricity per unit of fuel heat input with emissions of 781 kgCO2/MWh (1000/1.28 = 781), about 22% reduction. USC plants could achieve up to 700 kg/MWh with post-combustion carbon capture (Tramošljika et al., 2021).

Box 2. Technology Modernization for Efficiency_ Global Practices

- In Japan and Korea, supercritical technology was adopted before 2000. These countries now have high-performance coal plants with average efficiencies above 40%. These countries have now adopted USC technology. Yokosuka (Japan) is one of the 22 new coal-fired power plants planned to be built in Japan by 2025, equipped with two USC coal-fired units of 650MW capacity each.

- Germany's RWE power, a lignite-fired power plant, uses USC technology with an efficiency of 43.2%. A record-high net efficiency of 47.5% was achieved by the RDK Block 8 USC unit in Germany.

- NTPC, India's leading power generator, has commissioned the country's first USC unit having a capacity of 660 MW at Khargone in Madhya Pradesh, with operational efficiency of 41.5%, 3.3% higher than the conventional SC ones. The high efficiency will result in less coal consumption for generating the same amount of electricity vis-à-vis SC plants and will reduce 3.3 % CO_2 emissions.

- Bangladesh commissioned a 1,320 MW USC coal-fired power plant in a joint venture with China in 2022.

- China's share of SC and USC is increasing rapidly. For instance, China's Huaneng Yuhuan power plant (recently commissioned) is equipped with four USC coal-fired power generating units of 1,000MW capacity each. New units also incorporate high-efficiency dust removal and desulphurization.

Sources: (Tramošljika et al., 2021), IEA (2012), and
https://www.nsenergybusiness.com/projects/yokosuka-coal-fired-power-plant/
https://www.rwe.com/en/the-group/countries-and-locations/neurath-power- plant/#:~:text=Most%20modern%20power%20plant%20of%20its%20type&text=Like%20the%20BoA%20unit%20K,to%20cleaning%20the%20flue%20gas.
https://www.ntpc.co.in/en/media/press-releases/details/ntpc-commissions-india%E2%80%99s-first-ultra-super-critical-plant-0
https://www.aa.com.tr/en/asia-pacific/bangladesh-launches-its-largest-thermal-power-plant/2541508
https://www.power-technology.com/projects/yuhuancoal/

Indeed, the environment is of concern for Pakistan, as it is already among the world's most vulnerable countries. The only thing that needs to be done is to focus on the most efficient technologies. In Pakistan, it is expected that even after developing Thar coal at full scale, carbon emissions will be twenty times lower than the fast-growing and developed economies on an absolute basis and five times lower than the global average per capita basis (Rizvi, 2022). With high-efficiency and low-emission technologies, the emissions from coal-fired power generation would be reduced even more.

The technology used in coal plants is one part of the equation. Transporting Thar coal to a power plant is also significant. Although, there is no railway link with the Thar coal site. The coal plant in Sahiwal should have been avoided due to the high cost of electricity generation and the negative environmental impact caused by the 1200 km rail journey required to transfer imported coal from the port to the plant site (Cheema et al., 2022). It has been determined that the Sahiwal coal power plant has caused damage to fertile agricultural land, contaminated canal water, and polluted the air[19]. The plant's location is significant not only in terms of cost-effectiveness but also for its environmental implications.

Box 3. Mitigating the Environmental Impact of Coal Power Plants

- Efficient technology that conserves energy and resources is crucial. When constructing a new coal-fired power plant, it is essential to prioritize high efficiency and ensure that it can be easily retrofitted for CO2 capture and storage.
- Dry handling methods for coal combustion wastes, such as fly ash, eliminate the ecological risks associated with surface impoundments, such as metal contamination of wildlife.
- Recycling of coal combustion waste for use in cement, concrete products, and construction fills.
- Reusing wastewater in coal-fired plants through recycling.
- Ensuring that ash disposal and reclamation are managed in accordance with internationally recognized standards.
- Construction of plants near coal mines to avoid transport-related environmental impact.
- Relocating nearby communities.
- To establish stronger operational and maintenance protocols and better-coordinated land use planning.

Source: Coutinho, M. and Butt, H. K. (2014)

KEY TAKEAWAYS

Pakistan faces a significant challenge with its energy imports, which strains its energy security. Tapping into the country's energy resources is essential to address this issue. However, it is also crucial to consider the environmental impact of using local coal. When deciding on the best fuel mix for generating electricity in the future, it is critical to strike a balance between energy and capacity costs while prioritizing environmental protection.

- Due to long-term agreements, immediately decommissioning the existing plants with outdated technology is impossible. Commissioned SUBC power plants or pipeline technology must be upgraded or retrofitted to more efficient USC.

Additionally,

- A 20% blending of Thar coal in commissioned SC plants can be done to save foreign exchange reserves.

- Future commissioning of the power plants based on Thar Coal must not ignore power plant technology, its efficiency, and its location. All new power plants must be USC or even A-USC with higher efficiency to reduce future carbon and other pollutant emissions.

- It is crucial to adhere to all environmental safety protocols when operating a power plant that runs on coal.

ENDNOTES

2. https://www.iea.org/news/the-world-s-coal-consumption-is-set-to-reach-a-new-high-in-2022-as-the-energy-crisis-shakes-markets

3. In 2022, coal was the primary source of electricity generation, accounting for 36% of the share compared to 22% of natural gas share (Statista, 2023). These shares were 35% for coal and 24% for gas in 2020 (BP Statistical Review, 2022).

4. Fossil fuels are deemed suitable for meeting baseload demands.

5. https://www.barrons.com/articles/coal-use-hits-new-record-the-stocks-are-soaring-51671473657

6. https://www.secmc.com.pk/

7. China's energy output doubled from 1990 to 2005, and its electrification rate surpassed 99% due to the abundant coal reserves (World Coal Association Report 2012)

8. Coal mining provided more than seven million jobs worldwide in 2010 (World Coal Association Report 2012).

9. With the dollar hike and increase in global coal prices, the trend of the first two-quarters of FY2022 is doubling coal imports. The exact figure from the source is not available.

10. NEPRA Tariff Determination for FY2024.

11. The Government of Pakistan (GOP) had finalized a plan to shift CHIC Pak Power Company (Pvt.) in Gwadar from imported coal to Thar coal, but the Chinese government has refused this plan. During the PM's visit to China, he was required to modify the plan; the Chinese Foreign Ministry has sought written confirmation from the GOP (Ghumman, 2023).

12. Investing in coal-based projects in Pakistan was challenging as no Western bank was willing to finance the USD3 billion mega project. The Government of Sindh (GOS) recognized that developing Thar coal required a partnership between the Public and Private sectors and launched an International Competitive Bidding process for Thar Block II in 2008 to address this. As a result, a joint venture was formed between GOS and Engro, which led to the creation of SECMC in 2009. However, the joint venture came at the cost of a Sovereign Guarantee worth USD 700 Million (issued in 2012), which made the Thar coal project possible but also became a source of dollar capacity payment burden (details at https://www.brecorder.com/news/4392709).

13. Source: www.tradingeconomics.com

14. In FY2021, a verified amount of Rs. 3.94 billion was payable to the Wind Power Plants because of Non-Project Missed Volume (NPMV). The intermittent nature power plants (wind) enjoy the priority dispatch condition. Non-evacuation of available power due to transmission constraints from these plants makes them eligible for this payment.

15. PCC power technology with a stable operation record was developed long ago.

16. https://www.powermag.com/types-of-coal-and-fuel-blending-tips-for-coal-power-plants/

17. Although the technology used in the Lucky power plant is now USC, the reported efficiency is 39%.

18. A 1% gain in efficiency for a typical 700MW plant reduces 30-year lifetime emissions by 2,000t NOx, 2,000t SO_2, 500t particulates and 2.5 million tons of CO_2 (https://www.power-technology.com/projects/yuhuancoal/)

19. https://dailytimes.com.pk/300805/environmental-impact-of-the-sahiwal-coal-power-plant/

REFERENCES

- Abbasi, A. H. (2014). Coal-Fired Power Generation in Pakistan Technology, Efficiency and Pollution. Centre for Research and Security studies. https://crss.pk/coal-fired-power-generation-in-pakistan-technology-efficiency-and-pollution/

- ADB (2022). Pakistan: Jamshoro Power Generation Project, Environmental Monitoring Report. Available at https://www.adb.org/sites/default/files/project-documents/47094/47094-001-emr-en_26.pdf

- Ali, S. (2022). Solving the Energy Crisis is a "Now or Never" for Pakistan: The Future is Thar! Daily Pakistan, April 22. Accessed at https://en.dailypakistan.com.pk/22-Apr-2022/solving-the-energy-crisis-is-a-now-or-never-for-pakistan-the-future-is-thar

- Ali, S. A. (2022). Local But Complicated. The News, July 30. Accessed at https://www.thenews.com.pk/print/978135-local-but-complicated

- Alkon, M., Heb, X., Parisc, A. R., Liaod, W., Hodsone, T., Wandersf, N., and Wangg, Y. (2019) Water security implications of coal-fired power plants financed through China's Belt and Road Initiative. Energy Policy, 132, https://doi.org/10.1016/j.enpol.2019.06.044.

- Bhandary, R. R. & Gallagher, K. S. (2022). What drives Pakistan's coal-fired power plant construction boom? Understanding the China-Pakistan Economic Corridor's energy portfolio. World Development Perspectives, 25, https://doi.org/10.1016/j.wdp.2022.100396

- Cheema, T.B, Haque, N. U. and Malik, A. (2022). Power Sector: An Enigma with No Easy Solution. PIDE-RASTA.

- Coutinho, M. and Butt, H. K. (2014). Environmental Impact Assessment Guidance for Coal Fired Power Plants in Pakistan. Islamabad: IUCN Pakistan.

- Ghumman, M. (2023). "Gwadar Plants on Thar Coal: Two Chinese Loans to be Confirmed Soon." Business Recorder, January 19. Accessed at https://www.brecorder.com/news/40221115

- IEA (2012). Technology Roadmap: High-Efficiency, Low-Emissions Coal-Fired Power Generation. International Energy Agency, OECD.

- JICA (2013) Data Collection Survey on Thar Coal Field in Pakistan. https://openjicareport.jica.go.jp/pdf/12113221_01.pdf

- JICA (2016) Preparatory Survey on Lakhra Coal Fired Thermal Power Plant Construction Project in Pakistan. https://openjicareport.jica.go.jp/pdf/12267449_01.pdf

- JICA (2016). https://openjicareport.jica.go.jp/pdf/12267431_02.pdf

- Kumar, G. N. and Gundabattini, E. (2022). Investigation of Supercritical Power Plant Boiler Combustion Process Optimization through CFD and Genetic Algorithm Methods. Energies, 15, 9076. https://doi.org/10.3390/en15239076

- Larson, A. (2021). Types of Coal and Fuel Blending Tips for Coal Power Plants

- NEPRA (2022). State of Industry Report, National Electric Power Regulatory Authority, Islamabad.

- PACRA (2020) Coal Mining and Trading: Sector Overview. https://www.pacra.com/sector_research/-Sector%20Presentation%20-%20Coal%20July%202020_1594463009.pdf

- Rizvi, S. A. F. (2021). The Case of Thar Coal for Pakistan. Available at https://macropakistani.com/thar-coal/

- Sheikh, H. (2022). Transition to Clean Energy: How is power, capitalism and politics perpetuating coal use in Pakistan? Pakistan's Growth Story, November 16. Available at https://devpakblog.com/2022/11/16/transition-to-clean-energy-how-is-power-capitlaism-and-politics-perpetuating-coal-use-in-pakistan/

- Sloss, L. L. (2014) Blending of coals to meet power station requirements. IEA Clean Coal Center. Accessed https://usea.org/sites/default/files/072014_Blending%20of%20coals%20to%20meet%20power%20station%20requirements_ccc238.pdf

- Tramošljika, B., Blecich, P., Bonefačić, I., and Glažar, V. (2021). Advanced Ultra-Supercritical Coal-Fired Power Plant with Post-Combustion Carbon Capture: Analysis of Electricity Penalty and CO2 Emission Reduction. Sustainability 2021, 13, 801. https://doi.org/10.3390/su13020801.