Advancing reforms for cleaner and sustainable use of Indian coal

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Abstract. Coal plays a crucial role in India's energy security, meeting ~55% of the country's energy demand. With one of the largest coal reserves globally (~386 billion tonnes), India's coal is essential for key industries such as power, steel, cement, and fertilizers. However, the quality of domestic coal, especially coking coal, is generally lower than that of international sources, with higher ash content and lower coking properties. Domestic coal production and consumption have doubled over the past decade, reducing the proportion of coal imports by ~20%. Despite this, imports, especially coking coal for the steel sector, remain significant. To reduce dependence on imports, the government aims for 1.5 billion tonnes of domestic coal production by financial year 2030 (FY30), including 140 million tonnes of coking coal. Technological advancements like reflux classifiers and froth flotation cells are essential for improving the quality of domestic coal and enhancing its efficiency. Cleaner coal technologies are crucial for reducing emissions and ensuring sustainable coal use. Proactive government measures have boosted domestic coal supply, but further innovations and policy measures are needed to encourage the adoption of advanced coal beneficiation techniques. This will improve coal quality, reduce imports, and contribute to sustainable economic growth

1. Introduction

India is the world's second-largest producer and consumer of coal [1], and it is central to the country's energy mix, especially in electricity generation [2]. In FY23 coal accounted for 55% of primary energy consumption and approximately 72% of electricity generation [7,8]. While renewable energy sources like solar and wind are gaining ground, coal is likely to remain dominant for the foreseeable future due to India's vast reserves, established infrastructure, and energy security needs [2]. However, the environmental costs of coal mining and combustion, particularly in terms of greenhouse gas emissions and air pollution, necessitate reforms that can reduce its negative impact while maintaining its role in India's energy matrix.

This paper discusses the requirement for advancing reforms to make coal usage cleaner and more sustainable, focusing on both policy and technological solutions. It explores key strategies for cleaner coal mining, more efficient combustion technologies, and the integration of carbon capture and storage (CCS) technologies, as well as regulatory frameworks for enforcing stricter environmental standards. India's Energy Mix will have Coal as dominant source of energy, despite the increasing focus on renewable energy by FY2030 as shown in Figure 1.

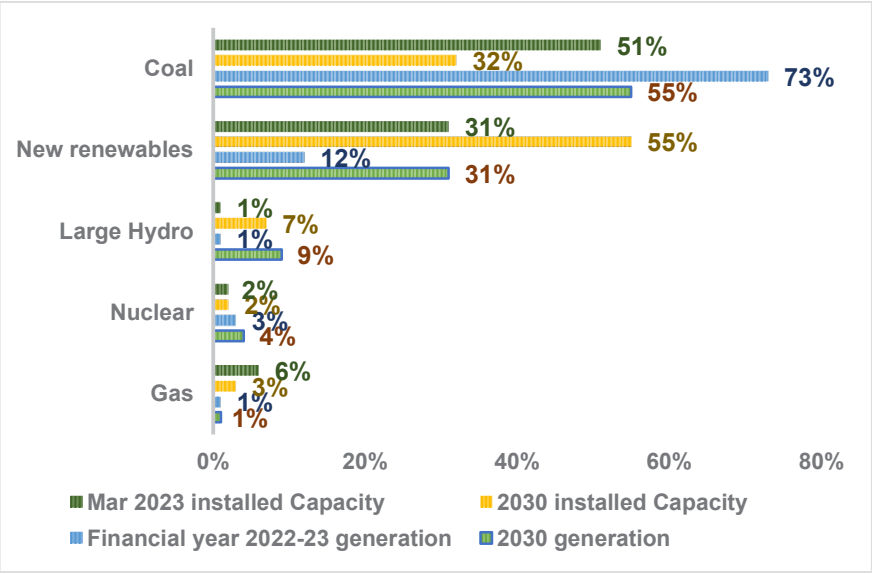

Fig.1. Energy mix of India [7]

2. Coal resources

India's reliance on coal is rooted in its vast coal reserves and the established infrastructure for coal-fired power generation. India is home to the fourth-largest coal reserves in the world, with an estimated geological resource of 389.4 billion tonnes (BT) as on 01.04.2024 (including the resources mined out or sterilized) up to the maximum depth of 1200 m [3]. The proven resources, i.e. those available for extraction in terms of i.e. economically viable, account for almost 54% [3].

Coking coal (prime, medium, and semi) together accounts for 36.81 BT (9.45%) of the total reserves whereas Non-Coking Coal and tertiary coal reserves accounts for 352.60 BT (90.54%) in India. Of the total reserves, **proved** reserves stand at 212.21 BT (54.49%), **indicated** reserves are 148.71 BT (38.19%), and **inferred** reserves are 28.50 BT (7.32%). About 80% of coal reserves in India are situated in Eastern part of the country [3].

3. Current trends in coal production and imports

Over the past decade, India has seen a substantial increase in both domestic coal production and consumption. The country's coal production has nearly doubled, meeting a significant portion of its energy demand. Coal imports, however, have also increased during this period, although the share of imports has reduced by approximately 20%, thanks to improved domestic coal production.

India has produced 997 Million Tonne (MT) of coal including 66.55 MT of coking coal and 931MT of non-coking coal in FY24 with a CAGR of 5.2% in last 10 years. However, India is still importing superior quality of Coal to bridge the gap between demand and supply of desired quality for specific sectors [2]. Trend of increase in India's coal production is shown in Figure 2.

Figure in Million Tonne

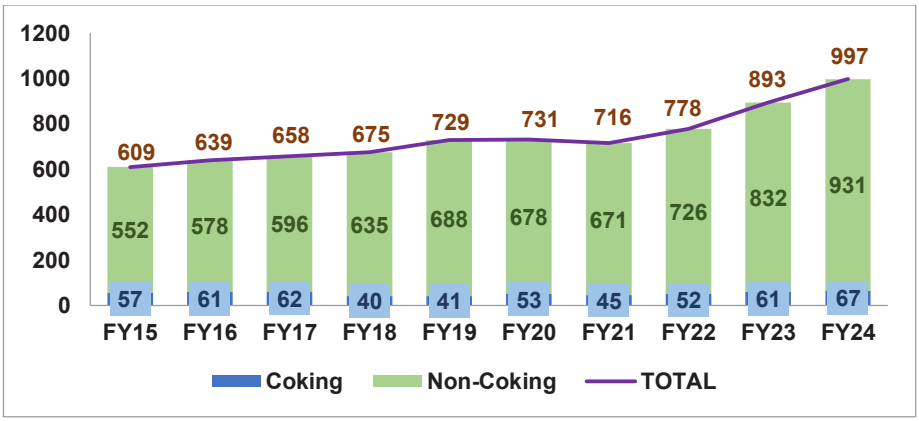

Fig.2: Trend of coal production in India

Indian non-coking coal is primarily used in power generation, cement production, sponge iron manufacturing etc. It serves as the main fuel for thermal power plants, contributing 72% to electricity generation in India. In the cement industry, non-coking coal fuels kilns for clinker production, while in the sponge iron sector, it acts as a reducing agent in iron production. Additionally, non-coking coal is being explored to utilize in coal gasification for producing syngas, which supports chemical and petrochemical industries. It is also blended with higher-quality coal in power plants to optimize combustion efficiency. Despite its higher

ash content and lower efficiency compared to coking coal, non-coking coal remains vital to several industrial sectors in India. The coking coal in India is mainly used as a fuel in steel industries. India, has only a small reserve of coking coal suitable for blast furnace operation which can be utilized directly by steel mills.

Indian coking coal is characterized by relatively high ash content (18-49%), low vitrinite, lower rank, poor caking/coking properties, low moisture content (2-10%), low sulphur content (0.2-0.7%), and low calorific values (ranging from 2500–5000 kcal/kg). Additionally, it contains relatively high levels of toxic trace elements, making coal beneficiation crucial for both economic and environmental reasons. Coal beneficiation involves the removal of undesirable materials, such as shale and sand, through separation processes that differentiate between the physical and surface properties of coal and its mineral matter. The main objective of this process is to reduce the ash content in Indian coal [4].

To meet industry demands, superior quality non-coking coal is imported by coast-based power plants, non-regulated sectors, and steel industries for use as PCI (Pulverized Coal Injection) coal, leading to significant outflows of foreign exchange. Steel industries are also importing coking coal having (9-12% Ash) which is blended with beneficiated domestic coal (18% ash) for steel making. With the current technology, domestic coal can only be used to a limited extent by blending it with imported coals after beneficiation. Due to the quality issues of domestic coking coal and its limited availability, Indian steel industries are heavily reliant on imports of low-ash coking coal (9-12%), Therefore, prioritizing the beneficiation of domestic coal is essential to reduce dependence on imports and enhance the quality of coal for domestic industries.

India has been heavily reliant on coal imports, with a total of 264.5 million tonnes (MT) imported, primarily from countries like Indonesia (43.74%), Australia (16.81%), South Africa, Russia and others as highlighted in Figure 3. This results in a significant outflow of the country's economy as highlighted in Figure 4, despite having substantial domestic coal reserves [5].

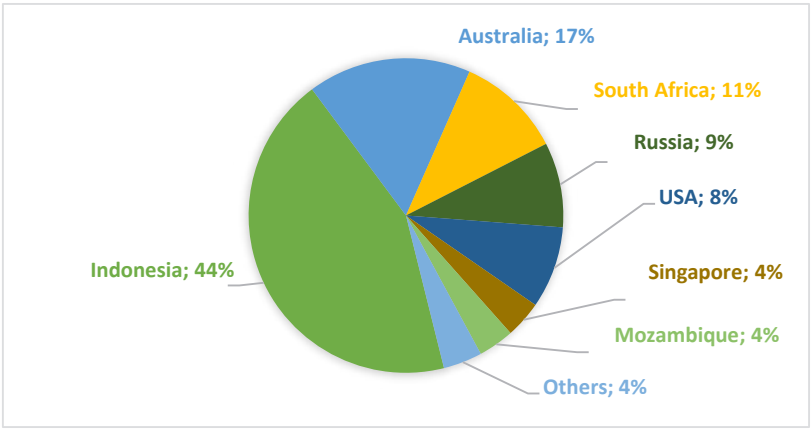

Fig.3: Countries - India importing coal

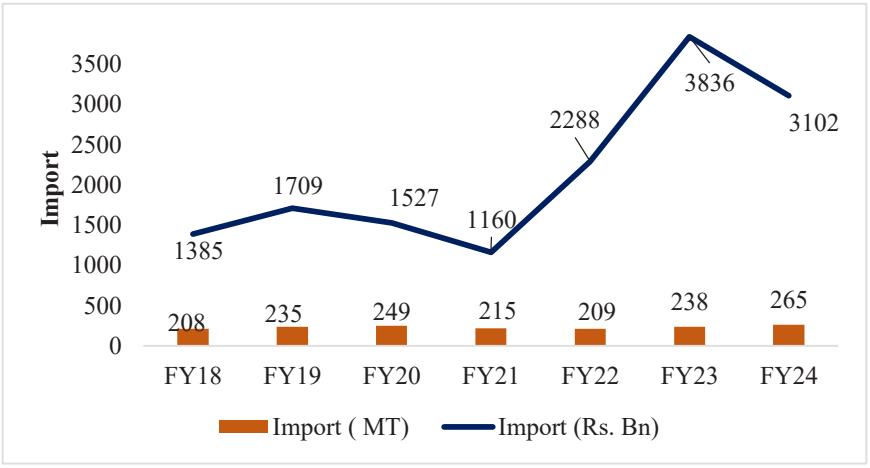

Fig.4: Volume and value of coal imports in India.

India has also engaged in coal exports, sending 1.54 million tonnes (MT) to neighbouring countries such as Nepal, Bangladesh, the UAE, Oman, Bhutan, and others as mentioned in Figure 5 below. This highlights India's position as a major coal importer and exporter, balancing its energy needs with regional trade commitments [5].

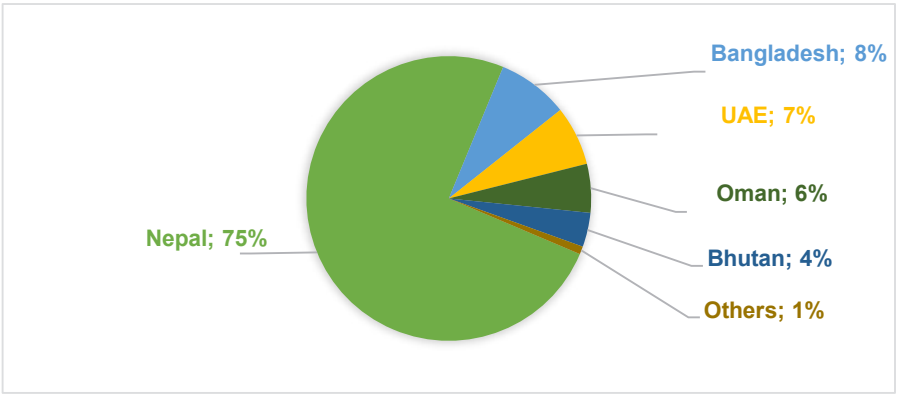

Fig.5: Countries - India exporting coal

4. Future demand for coal

With rapid economic growth, India's future energy requirements are expected to increase rapidly. Being the single largest consumer of coal, the power sector is likely to be one of the major segments shaping the demand for the fuel in future. In addition, demand from industries such as steel and cement, which are key to infrastructure development, will also see a rise in demand for coal. Hence, the Ministry of Coal has set a goal to produce 1.3 billion tonnes of domestic coal by FY27 and 1.51 BT by FY30 to advance the vision of Atma-Nirbhar Bharat ensuring India's energy security by substituting imported coal with domestic coal. The following table depicts the industry-wise coal demand projected up to fiscal 2030 in India:

Table 1: Sector-wise demand of coal in India

Figures in Million Tonne

Year	Fertilizer	Cement	Steel	Power	PCI+ DRI+ Thermal	Other	Total
2024-25	2	110	111	915	162	76	1376
2025-26	4	120	131	922	186	80	1443
2026-27	5	125	135	950	193	83	1491
2027-28	5	130	137	979	201	84	1536
2028-29	5	140	143	1028	206	88	1610
2029-30	5	145	148	1059	214	94	1665

Note: The coking coal demand of India projected at 9-12% Ash which will include blending of domestic coal with imported coal. The gap of demand of coal in India and production projection will be met through import of coal.

5. Mission coking coal

In August 2021, the Ministry of Coal launched 'Mission Coking Coal' as part of the 'Atma-Nirbhar Bharat' initiative to boost the production and utilization of domestic coking coal in India by 2030. This mission aims to reduce coking coal imports through transformative measures, including increasing domestic coking coal blending in steelmaking from the current 10% to 30%, ramping up domestic raw coking coal production to 140 million tonnes (MT) by 2030, and enhancing the country's washing capacity to 58 MT by FY30, producing 23 MT of washed coal with 18% ash content. The mission focuses on key areas such as new exploration, production enhancement, expanding washing capacity, and the operationalization of new coking coal mines, all aimed at reducing dependency on coal imports and strengthening India's self-reliance in coal production [6, 7].

5.1. Setting up washeries

Coal India Limited (CIL) has planned for setting up of 8 new coking coal washeries with a total capacity of 21.5 MTPA, which will help reduce the environmental impact while meeting industry demands. Additionally, CIL plans to monetize old washeries, which have outlived their lives, to optimize resources and ensure sustainability in coal processing operations. To reduce coal imports, several measures are being implemented, including the introduction of stamp charging technology for steelmaking by FY30, which will increase the blending percentage of coking coal in steel production to 30%. However, the country needs to expand washing capacity from 58 MT to 140 MT by 2030, supporting the steel sector's demand and further substituting coal imports [7].

6. Challenges in domestic coal utilization

India's domestic coal faces several challenges that hinder its optimal utilization:

6.1. Low quality

A major issue is the high ash content in domestic coal, particularly in coking coal, which impacts its utilization in blast furnace designed to take (9-14% Ash) coal for steel making. Also, the low-quality non-coking coal available in India also makes it less competitive compared to international standards efficiency of power plants and industrial processes [8].

The reason for the huge import partly lies in the inherent difference between quality of domestic coal and imported coal. Indian coal being of Drift origin is heterogeneous in nature due to which it has higher ash and moisture content as compared to relatively uniform coal seam (in-situ origin) found in other countries such as Australia, Indonesia, South Africa, etc. Low ash high calorific coal is not available in sufficient quantity to completely meet the demand of its consumers. Beneficiated coal can be an inexpensive substitute for imported coal.

6.2. Inadequate coal beneficiation

Domestic coal often requires beneficiation to improve its quality before it can be effectively utilized. The absence of state-of-the-art beneficiation technologies such as reflux classifiers, teetered bed separators, and froth flotation cells limits the potential to enhance coal quality. This results in inefficient coal use and higher environmental emissions.

6.3. Environmental concerns

The combustion of coal, particularly low-grade coal, produces significant amounts of carbon dioxide (CO_2), particulate matter, sulphur dioxide (SO_2), and nitrogen oxides (NOx). These emissions contribute to air pollution, health hazards, and climate change.

6.4. Pushing power companies to transport washed coal for their long-distance plants

In view of the rising global environmental concern, the Government of India, issued guideline in 2014 according to which a stand-alone thermal power plant (of any capacity) or a captive thermal power plant of installed capacity of 100 MW or above, located beyond 500 km from the pit head and those located in urban areas or ecologically sensitive areas or critically polluted industrial areas irrespective of their distance from the pithead (except any thermal power plant using Circulating Fluidized Bed Combustion or Atmospheric Fluidized Bed Combustion or Pressurized Fluidized Bed Combustion or Integrated Gasification Combined Cycle technologies or any other clean technologies as may be notified by the Central Government in the Official Gazette) shall use raw or blended or beneficiated coal with ash content not exceeding 34% on quarterly average basis, with effect from 5th June 2016. Impact of this guideline, a number of non-coking coal washeries were set up in the country by private players near the coal mines to wash non-coking coals and supply washed coal to distant power producers.

However, The Government of India revised the guideline dated 21st May 2020 termed as Environment (Protection) Amendment Rules, 2020, wherein use of coal by thermal power plants without stipulations as regards ash content or distance has been permitted subject to certain conditions. It may be mentioned that by washing of non-coking coal, TPS get washed coal of consistent quality and size which significantly reduces operational problems [9, 10].

6.5. Inefficient utilization in industries

In sectors such as steel, cement, and power generation, inefficient use of coal leads to higher costs and lower productivity. For instance, blending high-ash coal with imported low-ash coal in power plants reduces overall efficiency and increases emissions.

6.6. Low utilization of existing washeries

India has at present 9 coking coal and 30 non-coking coal washeries having average capacity utilization of 30-40% only due to inconsistency in run of mine (RoM) coal size and also quality in terms of ash and moisture. This inconsistency of RoM coal leads to ineffectiveness in washery performance such as low-capacity utilization, difficulty in maintaining the washed coal quality, increased wear & tear of mechanical equipment, etc.

Another factor of low utilization of washeries is not giving direct long term raw coal linkages through FSA (Fuel Supply Agreement) or MoU (Memorandum of undertaking) by coal companies.

6.7. Reject disposal issues

Government of India has issued reject disposal policy in 2021 to regulate by-product of washery. According to policy the by-products of the washeries having GCV 1500 kcal/kg or more fall in the graded coal category and cannot be disposed as rejects in mine voids/low lying area but in an eco-friendly manner. About 20% of the total plant capacity are generated as washery rejects. Availability of land for temporary storage of rejects for large capacity plants shall be a constraint. Evacuation of the same by finding market for such coals is a hurdle for washery operators and affects the operation of the washeries [11].

The solution lies in utilizing the rejects by Fluidized Bed Combustion (FBC)/Circulating Fluidised Bed Combustion (CFBC) plants located at the mine/washery end. FBC/CFBC plant again shall require land for the plant in the vicinity of washery [11].

7. Technological innovations and cleaner coal utilization

To address these challenges, India has focused on the need for technological innovations and cleaner coal utilization methods. Some of the key technological advancements and strategies include:

7.1. Setting up coal beneficiation plants with advanced technology

Very few Indian Coal Washeries installed prior to 2010 were having fine coal treatment in their washing circuits. New washeries are planned based on advanced beneficiation technologies like reflux classifiers, teetered bed separators, and spirals to treat the fine coal (-0.25mm) in the coal beneficiation circuit. This can improve the quality of Indian washed coal, reduce its ash content and making it more efficient for combustion. These technologies will help increase the calorific value of domestic coal, reducing the need for high-quality imports. However, there is need for policy to set up more washeries plants in country to meet the demand of country and considering eco-friendly utilization of coal.

7.2. Fines recovery and blending optimization

Indian coal is blended with imported coal before utilizing in coke oven or specific boilers. Using computerized blending systems and fines recovery techniques can optimize coal utilization by improving the efficiency of combustion. These methods ensure that the right mix of coal is used for different industrial applications, thereby reducing waste and

emissions. Regulations are required for beneficiation of fines in coal washeries to protect national resources.

7.3. Coal gasification

Coal gasification, a process that converts coal into syngas (a mixture of hydrogen, carbon monoxide, and carbon dioxide), can offer a cleaner and more efficient alternative to traditional coal combustion. Gasified coal can be used in power plants, petrochemical production, and steel manufacturing, reducing emissions and improving energy efficiency.

To promote coal production and ensure surplus supply, while transitioning towards cleaner energy alternatives, recognizing the need to address environmental concerns and reduce carbon emissions, the Indian Government set a vision fostering a resilient and sustainable energy ecosystem. Coal Gasification Mission was launched which aims to gasify 100 million tonnes of coal by 2030 through surface coal/lignite gasification projects. To support these initiatives, a financial assistance scheme has been proposed to promote Coal/Lignite Gasification Projects by Government PSUs and the Private Sector, with an sallocation of ₹ 8500 crores for incentives towards coal gasification projects. The scheme aims to demonstrate the financial and technical viability of gasification projects, accelerate markets for downstream products, and create an additional value chain in the economy for coal [12].

The adoption of gasification technology in India will revolutionize the coal sector, reducing reliance on imports of Natural Gas, Methanol, Ammonia, and other essential products. It will contribute to India's vision of becoming Atma-Nirbhar and create a surge in employment opportunities. The implementation of coal gasification is expected to make significant contributions to the nation's development by reducing imports by 2030.

7.4. Direct reduced iron (DRI) for steel making

Coal gasification may also be used for steel making. Synthesis gas can be used for producing the direct reduced iron in a shaft furnace (used in steel making). Use of gas based DRI can help in avoiding requirement of imported Coal for DRI. National steel policy 2017 has project demand of 100 MT non-coking coal for DRI route steel making.

Presently, in India only JSPL is commercially using domestic coal DRI based for steel making. The plant is based on SLTC, S Africa & Lurgi, Germany technology taking feed stock of non-coking coal of 34-35% ash with coal requirement of 270 ton/hr and producing 2,25,000 Nm^3/h of syngas. Measures are required by Indian government for setting up domestic coal DRI based plants for steel-making to curb imports [13].

7.5. Stamp charging technology for steelmaking

The stamped charging of coal, developed in Europe and adopted in China and India, allows the use of high volatile poor coking coal, soft and semi soft coal as well as inert-like petroleum coke and anthracite without impairing coke quality. Only Tata Steel is using stamp charge battery for steelmaking in India. It is being planned to implement stamp charge battery for steelmaking to increase the blending percentage of domestic coking coal to 30% from the current level of 10% to reduce the import of coal. Policies required for steel sector to mandate use of stamp-charging technology for new/expansion steel plants is required to utilize Indian Coking coal and protect national interest [6].

7.6. Carbon capture and storage (CCS)

Implementing CCS technologies in coal-fired power plants can significantly reduce CO_2 emissions. CCS involves capturing CO_2 emissions from the combustion process and storing them underground, preventing their release into the atmosphere. This technology is crucial

for mitigating the environmental impact of coal combustion and aligning with global climate goals.

8. Policy and regulatory measures

To facilitate the adoption of cleaner and more efficient coal technologies, India has implemented several policies and needs to implement more supportive policy measures:

8.1. Stricter environmental regulations

The government needs to enforce stringent emission standards for coal-fired power plants, requiring them to adopt advanced pollution control technologies. Implementing carbon pricing and emissions trading schemes can also encourage coal plants to reduce their carbon footprint.

Also, a study "Economic & Environmental Impact of Coal Washing in India" was carried out by Tata Energy Research Institute (TERI) in November 2020 for assessment of economic impact on use of washed coal in power plants. The study suggested that use of beneficiated coal is beneficial for power plants if power plants are receiving coal over longer distances that are more than 600kms which needs to be implemented.

8.2. Promoting Indian coal for using high grade thermal coal as PCI coal

Superior quality non-coking coal is imported PCI coal for steel making. Pulverized Coal Injection or popularly known as PCI coal is high grade thermal coal, having ash of <10%, extensively used in Blast Furnaces as a partial replacement of the metallurgical coke for steel making. PCI is a well-established technology today to produce hot metal (HM) in a Blast Furnace.

Presently, ~15 MT Pulverized Coal Injection (PCI) coal is imported in the country for steel making. As per national steel policy, 30 MT PCI coal demand is projected by FY30. This PCI coal, which is completely imported can be substituted by washing high-grade thermal coal to produce coal ash of <10%. CIL mines are producing 20 MT high grade thermal coal presently and projected to produce 60 MT by FY30 which can be utilized as PCI coal to reduce imports in steel sector. However, to utilize Indian high grade thermal coal as PCI, it needs to be beneficiated to reduce ash%. Therefore, use of value-added coal through beneficiation policy needs to be brought into the country.

8.3. Reforms in coal linkage policy

The Indian government has undertaken several reforms to promote the utilization of coal through the Weighted Average Distance (WDO) route, aiming to optimize coal usage, through washery route, reduce environmental impact and boost energy security. These reforms involve providing 30 years long-term linkage, creation of new-sector under non-regulated sector linkage auction policy.

Also, to promote coal gasification projects, under the Non-Regulated Sector (NRS) linkage auction policy, a new sub-sector of 'Production of Syn-Gas leading to coal gasification' was created in 2022. The gasification project proponents are required to participate under the linkage auctions in this sub-sector to avail a coal linkage. NRS linkage auction policy states that the initial floor price shall be set at the relevant CIL / SCCL ROM price and the bidders shall bid for premium above this price [12].

8.4. Capacity building and research

Investing in research and development for coal technologies, including CCS, advanced combustion methods, and coal gasification, will enable India to stay at the forefront of cleaner

coal technologies. Collaborations with international experts and organizations can also help accelerate the adoption of these technologies.

9. Conclusion

Coal will continue to play a central role in India's energy and industrial sectors for the foreseeable future. However, to ensure that this role is sustainable, India must adopt cleaner, more efficient coal utilization practices. Technological innovations in coal beneficiation, cleaner combustion, and carbon capture, along with supportive policy measures, are critical to improving the quality of domestic coal and reducing environmental impacts. By advancing these reforms, India can achieve its goal of energy self-reliance while minimizing the negative consequences of coal use on public health and the environment. These efforts will be key to balancing India's energy needs with its sustainable development goals, ensuring a cleaner and more prosperous future**.**

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