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Coal Mining in India: A Multidimensional Analysis of Sustainability Challenges and the Imperatives of a Just Energy Transition

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This study fills a critical gap in the literature by concurrently analysing the sustainability challenges of coal mining and the just transition imperatives in India, a perspective largely absent in existing energy policy research. Major findings include: (1) coal production exceeded 1 BT in FY2024–25 while renewable capacity reached 50% of non-fossil targets five years early; (2) environmental costs include 35% native land cover loss and double the national TB incidence in mining areas; (3) 1.4 million livelihoods depend on coal, yet no formal just transition policy exists. The study provides a comparative policy framework (EU, USA, UK, South Africa) and recommends capacity building, legal reform, and equitable resource access. India is navigating its role as the second-largest coal consumer while pursuing ambitious renewable-energy targets. The analysis delves into the economic factors driving the predominance of coal, environmental and social costs associated with coal mining, and rapid expansion of India's Renewable Energy Sector (RES). Additionally, it addresses the concept of a "Just Transition" for coal-dependent communities in the region. This study offers insights into harmonizing energy security with sustainability and social justice, providing policy recommendations for a balanced approach to India's energy policy. By examining these interconnected dimensions, this analysis seeks to contribute to the discourse on energy sustainability and provide actionable insights for policymakers and stakeholders in India.

Major Findings: *India's coal and renewable sectors are expanding simultaneously, but coal mining causes severe land degradation (35% loss) and public health crises (TB double national average). A just transition framework is absent, risking 1.4 million livelihoods; comparative policy learning from EU/USA/UK/South Africa is urgently needed.*

Keywords: *Coal Mining, Energy Security, Environmental Degradation, Just Energy Transition, Land Use Change, Public Health Crisis, Renewable Energy, Social Justice, Sustainability Challenges*

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1.0 Introduction

India's energy strategy is founded upon four principal pillars: (1) the rapid expansion of Renewable Energy (RE) sources, including solar (97.87 GW), wind (48.16 GW), and hydroelectric power (52.07 GW); (2) the gradual reduction of coal's proportion in the energy mix while utilizing its domestic abundance to ensure base load security; (3) the prioritization of coal over oil and gas due to limited domestic petroleum reserves; and (4) the localization of energy sources, such as rooftop solar, decentralized RE, and coal pit-head plants, to minimize long-distance electric transmission losses and reduce reliance on imports. India's energy landscape

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is characterized by a complex interplay between its dependence on coal and its commitment to renewable energy. Notably, there is a paucity of integrated studies that concurrently evaluate the sustainability deficits of coal mining, the rapid growth of renewable energy, and the gaps in just transition policies within Indian energy literature. Such studies are essential for balancing the nation's 2070 net-zero commitment with the livelihood security of over 1.4 million individuals reliant on coal.

This report examines the multifaceted challenges and opportunities presented by India's dual energy mandate, focusing on the sustainability issues surrounding coal mining and the imperatives of a just energy transition. India is at a critical juncture, balancing its position as the second-largest consumer of coal with its ambitious targets for renewable energy adoption. Coal currently contributes 55% to India's national energy mix and drives more than 74% of total power generation[1]. However, the country has also made significant strides in renewable energy, surpassing its target of sourcing 50% of its installed electricity capacity from non-fossil fuel sources five years ahead of schedule[2]. This significant dependence on coal has deep-rooted historical and economic reasons, including the abundance of domestic coal reserves and established infrastructure for coal-based power generation[3]. However, the environmental and health implications of coal consumption have become increasingly apparent, prompting a reevaluation of the country's energy strategy[4]. Despite the dominance of coal, India has made remarkable progress in the renewable-energy sector. The country surpassed its target of sourcing 50% of its installed electricity capacity from non-fossil fuel sources five years ahead of schedule[5]. This underscores India's commitment to diversifying its energy portfolio and reducing its carbon footprint[6]. The rapid growth of solar and wind power installations has been particularly noteworthy, driven by favorable government policies, decreasing technology costs, and increased private sector participation[7]. This study delves into the economic drivers behind coal's continued dominance, exploring factors such as energy security, job creation, and the cost-competitiveness of coal-fired power plants. It also examines the environmental and social costs associated with coal mining, including air and water pollution, land degradation, and displacement of local communities. The analysis extends to the health impacts on miners and nearby populations, as well as the broader implications of climate change and India's international commitment to the Paris Agreement.

This study investigates the economic factors sustaining coal's predominance, the environmental and social costs associated with coal mining, and the rapid expansion of the renewable energy sector in India. It further explores the concept of a 'Just Transition' and addresses the socio-economic vulnerabilities faced by communities that rely on coal. By examining these interconnected aspects, this analysis aims to contribute to the ongoing discourse on energy sustainability in India and provide insights for policymakers and stakeholders engaged in this critical transition. India's energy landscape is characterized by a complex interplay between its reliance on coal and commitment to renewable energy sources. This study examines the multifaceted challenges and opportunities presented by India's dual energy mandate, focusing on the sustainability issues surrounding coal mining and the imperatives of a just energy transition. India is at a critical juncture, balancing its position as the second-largest consumer of coal with its ambitious targets for renewable energy adoption.

This study examines the rapid expansion of the renewable energy sector in India, focusing on the technological advancements, policy initiatives, and market dynamics that have facilitated the growth of solar, wind, and other renewable energy sources. It also addresses the challenges confronting the sector, including grid integration, energy storage, and the need for supportive regulatory frameworks. A critical component of India's energy transition is the concept of a "Just Transition." This study investigates the socio-economic vulnerabilities of coal-dependent communities and regions, assessing the potential impacts of mine closures and the transition away from coal-based industries. It discusses strategies to mitigate these impacts, such as skill development programs, alternative livelihood opportunities, and the potential repurposing of coal-mining areas for renewable energy projects. Furthermore, this study analyzes India's energy policies and their alignment with global sustainability goals by examining the country's Nationally Determined Contributions (NDCs) under the Paris Agreement, its participation in international climate initiatives, and the domestic policy landscape shaping

its energy sector. The role of public and private sector investments in driving the energy transition is explored, along with the potential for international cooperation and technology transfer to achieve Sustainable Development Goals (SDGs).

This analysis also explores the geopolitical ramifications of India's energy transition, focusing on its effects on regional energy dynamics, international trade relations, and global initiatives to address climate change. It further investigates India's potential to become a leader in renewable energy technology and sustainable development. By examining these interconnected dimensions, this analysis seeks to contribute to the ongoing discourse on energy sustainability in India and offer actionable insights for policymakers and stakeholders involved in shaping the country's energy future. The study concludes with recommendations for balancing immediate energy requirements with long-term sustainability objectives, underscoring the necessity of a comprehensive approach that integrates economic, environmental, and social considerations into India's energy transition.

1.1 Contextualizing India's Energy Imperative

India, acknowledged as the world's second-largest consumer of coal and possessing the fifth-largest coal reserves, is currently at a critical juncture in its energy transition and development[8]. The rapid economic growth of the nation, coupled with a swiftly increasing population, has resulted in a growing demand for energy resources, with coal remaining a fundamental component of the energy infrastructure[9]. Currently, coal constitutes approximately 55% of India's national energy mix and is responsible for over 74% of the country's total power generation capacity, underscoring its critical role in ensuring energy security and stability[10,11]. The primary challenge confronting the nation is managing its significant reliance on this carbon-intensive energy source while fulfilling its commitment to international climate agreements[5]. This complex balancing act necessitates a strategic approach that addresses immediate energy needs while aligning with global sustainability goals aimed at reducing carbon emissions and combating long-term climate change. Consequently, India's future energy policy must be meticulously crafted to facilitate a transition to more sustainable energy sources, ensuring economic growth and energy accessibility for all citizens, amid pressing environmental challenges.

1.2 The Central Paradox

The essence of this intricate analysis lies in a compelling paradox that underscores the simultaneous and unprecedented growth of both the coal industry and the renewable energy sector, which are traditionally perceived as being in direct opposition. In a remarkable historical achievement, India exceeded the significant benchmark of one billion tons (BT) in coal production during the provisional fiscal year (FY) 2024–25, marking a pivotal milestone in its industrial capabilities and the efficiency of its resource extraction processes[10,12,13]. This notable accomplishment coincided with the nation's celebration of another monumental milestone: achieving 50% of its total installed electricity capacity from non-fossil fuel sources, a commitment made at the COP26 summit and realized five years ahead of the original 2030 target[10,14-16]. The intricate and dynamic interplay of the growth trajectories of these two sectors is essential for comprehensively understanding the distinctive and multifaceted narrative surrounding India's ongoing energy transition, which is characterized by its unique challenges and myriad opportunities[17]. Furthermore, this dual trajectory reflects the complexities inherent in energy policy and economic development within the country and underscores the potential for synergistic coexistence between traditional fossil fuels and emerging clean energy technologies. Consequently, meticulous exploration of these simultaneous advancements is crucial for understanding the broader implications of sustainability and energy security in the context of a rapidly evolving global landscape that continually presents nations with new challenges and opportunities for improvement.

1.3 Scope and Methodology

This study offers a comprehensive and multifaceted analysis of the sustainability challenges arising from India's continued reliance on coal as its primary energy source. The analysis is systematically structured to elucidate the economic imperatives and strategic motivations that sustain the dominance of coal in India's energy landscape, utilizing contemporary data from the Ministry of Coal's annual reports and press releases[15].

Following this foundational assessment, this study meticulously examines the significant environmental repercussions and social costs associated with the coal sector, drawing on rigorous findings from a wide range of peer-reviewed literature. Subsequently, this study focuses on investigating the rapid acceleration of the renewable energy transition in India, providing a quantitative overview of the progress, and analyzing the strategic policies implemented to facilitate this shift over the past decade. In the concluding sections, the report addresses the critical human dimension of the "Just Transition," emphasizing the socioeconomic vulnerabilities of communities heavily reliant on coal for their livelihoods. It proposes a comprehensive policy framework aimed at promoting an equitable future for the affected population in the region. Ultimately, the interplay between economic sustainability, environmental stewardship, and social equity forms the crux of this study, underscoring the urgent need for a paradigm shift in energy policy that is inclusive and forward-thinking. Through this detailed exploration, this study aims to contribute significantly to the discourse on energy sustainability in India by offering actionable insights for policymakers and stakeholders involved in the transition.

2.0 Coal Mining in Indian Context

2.1 Production Milestones and Economic Drivers

India's coal industry has demonstrated significant growth, surpassing previous benchmarks and establishing new paradigms in the coal sector. Preliminary data for the fiscal years 2024–2025 indicate that India achieved a total coal production of 1047.57 million tonnes (MT), reflecting a growth rate of 4.99% compared to the 997.83 MT produced in the preceding fiscal year[10,13-15]. Similarly, coal dispatch, which pertains to the logistical process of transporting coal from extraction sites to various end users, reached a significant milestone by exceeding one billion tons, culminating in a total of 1024.99 MT, representing a growth rate of 5.34% over the previous year[3,14]. This remarkable expansion within the sector is primarily driven by the rapidly growing commercial and captive mining segments, which have collectively experienced a 28.11% surge in production[13]. The implications of such pronounced growth are multifaceted and complex, potentially influencing various aspects of both the economy and energy sector while simultaneously raising critical questions regarding sustainability and environmental impact. Consequently, the growth trajectory of the Indian coal sector reflects its capacity to scale production to unprecedented levels and underscores the intricate dynamics of demand and supply that continue to shape the future of the sector. Table 1 shows the historical and projected growth of energy sector from last 20 year to next 20 year.

The coal industry in India is predominantly characterized by the significant influence and operational control of state-owned enterprises, with Coal India Limited (CIL) accounting for 75% of the nation's total coal production, thereby underscoring its pivotal role in the energy sector[10,14]. In the fiscal year 2024–25, CIL not only achieved a record production milestone of 781.06 million tonnes (MT) but also set an ambitious target to increase its annual production capacity to one gigatonne (Gt) by the fiscal year 2028–29, reflecting its commitment to meeting the country's growing energy

Table 1. Energy growth of india from last 20 year to next 20 year

Energy Source	2005 (GW)	2025 (GW)	Avg. Growth (% p.a.)	2045 (GW) Projected
Coal Thermal	85	215	4.8%	550
Solar PV	0.01	97.87	80% (2005-25)	4200 (linear projection unstable)
Wind	3.4	48.16	14.5%	770
Large Hydro	32	52.07	2.5%	85
Total RE (incl. small hydro, bio)	38	242.8	9.9%	

demand[10]. Beyond its primary function of direct energy generation, the coal sector is a fundamental component of the energy infrastructure. This expanding energy pillar of the national economy is essential for supporting various industrial activities and significantly contributes to the overall economic stability of the country. As one of the eight core industries identified in India, this sector plays a vital role in the logistics and transportation framework of the nation, particularly through its substantial contribution to railway freight operations, which account for nearly 49% of the total freight revenue generated in the country. In the fiscal years 2022–23 alone, the coal sector generated impressive revenues exceeding Rs. 82,000 crores, highlighting its critical importance to the country's financial fabric[10,13-15].

Table 2 presents a detailed quantification of the recent growth trajectory within this critical sector, highlighting the dynamic and evolving nature of coal production and its broader economic implications for India. Each data point in the table numerically represents growth and reflects the ongoing development and strategic initiatives undertaken by the key industry stakeholders.

Upon analyzing this growth trajectory, it becomes increasingly evident that the coal sector will continue to exert a transformative influence on the formulation of energy policies and economic strategies in India in the foreseeable future. The interaction between state-owned enterprises such as Coal India Limited (CIL) and the broader economic environment will undoubtedly shape future investments, regulatory frameworks, and sustainability initiatives within the coal industry, necessitating further research.

2.2 Deeper Analysis: The Expanding Energy Pie

The simultaneous rise in coal production and renewable energy capacity may initially seem contradictory, challenging the conventional assumptions regarding energy transition dynamics[18]. However, this trend can be comprehensively understood through the "expanding energy pie" phenomenon, which posits that the overall demand for energy is increasing at an unprecedented rate[19]. In India, the rapid escalation in energy demand means that newly developed renewable energy capacities are primarily employed to meet this growing demand rather than directly replacing existing fossil fuel generation facilities. Coal, with its established infrastructure and inherent base-load reliability, continues to play a vital role in addressing the escalating energy needs of rapidly industrializing economies striving for sustained growth and development[20]. It is crucial to recognize that the current energy transition is not merely a zero-sum game characterized by the substitution of one energy source for another but rather represents a parallel and simultaneous expansion of energy resources aimed at fulfilling the ever-growing national energy requirements. Therefore, the coexistence of coal and renewable energy sources in India reflects a complex and multifaceted approach to energy generation that seeks to balance environmental sustainability with economic demands. In conclusion, the intricate interplay between these energy sources underscores the necessity of a diversified energy strategy that can effectively respond to the challenges presented by rapidly evolving energy landscapes.

Table 2. India's coal production and dispatch (FY 2023-24 and 2024-25)[14]

Metric	FY 2023–24 (Actual)	FY 2024–25 (Provisional)	Growth %
Total Production	997.83	1047.57	4.99%
CIL Production	773.65	781.06	0.96%
Captive & Others Production	154.16	197.5	28.11%
Total Dispatch	973.01	1024.99	5.34%

The expansion initiative, intricately aligned with broader governmental objectives, represents a pivotal element of a comprehensive strategic effort aimed at promoting national self-reliance in the coal sector. The government's recent approval of a substantial financial incentive of ₹8,500 crore, specifically designated for the development and implementation of coal and lignite gasification projects, exemplifies a forward-thinking approach intended to reduce foreign exchange outflow while enhancing the country's energy independence and sustainability[13,14,21]. The notable 8.4% reduction in coal imports from April to December 2024, resulting in significant savings of $5.43 billion, further substantiates the rationale behind this domestic-first energy policy[14,15]. This well-conceived strategy signifies a deliberate transition towards a more competitive energy supply model, heavily reliant on coal, while emphasizing domestic production to ensure the long-term security and resilience of the nation's energy future. Essentially, the government's multifaceted approach encapsulates a vision that harmonizes economic growth with environmental sustainability, positioning the nation to thrive in an increasingly dynamic and competitive global energy landscape[22,23]. Ultimately, this strategic shift reflects a commitment to fostering innovation and resilience within the energy sector, ensuring that the country can meet its energy demands while simultaneously enhancing geopolitical and economic stability.

2.3 Policy Stance on Coal Subsidiaries and Private Sector Complaints

The Government of India retains prime coal deposits for state-owned PSUs (Coal India Limited, SCCL) under the Coal Mines (Nationalization) Act, 1973, as amended. Private sector firms complain that "good deposits are not being offered to them". Only 40% of total coal-bearing area has been opened for commercial auction, and that too mostly partially explored blocks. Current policy statements for coal subsidiaries include: (i) Coal linkage auctions for power sector (SHAKTI scheme); (ii) Revenue sharing model for commercial mining (no fixed upfront payment); (iii) Rs. 8,500 crore incentive for coal gasification projects; (iv) Single-window clearance for coal mining. However, private players argue that PSUs retain high-grade, low-ash deposits near infrastructure, while auctioned blocks are often geologically challenging. This stance works as a future solution only if: (a) independent geological certification of all blocks before auction, (b) assured evacuation infrastructure for private miners, (c) competitive bidding without PSU advantage. Otherwise, India may miss private investment needed to achieve 1.5 BT coal production by 2030.

3.0 Environmental and Social Costs of Coal Mining: A Sustainability Report Card

3.1 Land Use Change, Deforestation and Habitat Los

Coal extraction significantly contributes to ecological degradation, with pronounced and increasing effects across India. Research focused on Central India, a key region for coal mining, has provided substantial evidence of environmental harm. The rapid expansion of mining activities, which grew from approximately 6.4 square kilometers to 30 square kilometers, has directly led to the destruction of nearly 115.3 square kilometers of Sal forest (Shorea robusta). A comprehensive analysis of land-use changes from 1994 to 2022 at three major mining sites revealed a 35% reduction in the original land cover[24]. Open-pit mining, which is responsible for approximately 90% of the country's coal production, is central to this issue. This method completely eradicates native vegetation and nutrient-rich soil, resulting in lasting damage to the landscape and ecosystems. Furthermore, this process generates a substantial volume of waste; the extraction of a single million tonnes of coal can produce 15 million tonnes of byproduct material, placing additional strain on the nation's limited land resources.

Table 3. Land use and forest loss in central indian coalfields (1994-2022)[14]

Land Cover Type	Percentage Loss due to Mining
Forest Cover	7.32%–17.61%
Water Bodies	5.0%–10%
Agricultural Lands	3%–5%
Overall Native Land Cover	35%

As shown in Table 3, degradation affected all major land cover categories. Forest cover exhibited the most significant decline, with a reduction ranging from 7.32% to 17.61% in the study area. Aquatic ecosystems and agricultural areas also experienced substantial decreases of 5-10% and 3-5%, respectively. The cumulative effect resulted in a 35% reduction in the region's original indigenous land cover. Consequently, the probability of land degradation has markedly increased owing to this expansion. Research indicates that between 25% and 40% of the land within the studied regions is currently classified as being at an elevated risk of degradation.

3.2 Water and Air Pollution

The extraction and subsequent combustion of coal result in the emission of a diverse array of harmful substances, including sulfur dioxide, nitrogen oxides, and various particulates that are detrimental to both human health and the environment. Furthermore, the accumulation of mine tailings, which contain high concentrations of heavy metals and other toxic pollutants, poses a significant threat to water quality and the integrity of soil ecosystems in mining areas. Although coal washing can enhance the thermal efficiency of combustion, it necessitates substantial water use, thereby imposing additional environmental stress on water resources[25,26]. Reports from the Ministry of Coal have outlined several strategies to mitigate these adverse impacts, such as the use of fog cannons to reduce airborne particulates, wheel-washing systems to minimize pollutant transport, and the establishment of Continuous Ambient Air Quality Monitoring Systems (CAAQMS) to evaluate the effectiveness of these interventions. However, the efficacy of these mitigation strategies is increasingly being questioned because of the rapid expansion of coal mining operations, which often surpasses the capacity of these technologies to address the resulting environmental degradation and pollution issues. Moreover, findings from various academic studies indicate persistently high levels of air and water pollution associated with coal mining, suggesting that while individual projects within the industry may be making commendable efforts towards sustainability, the cumulative environmental impact of the coal sector continues to escalate at a rate that significantly exceeds the capacity of current mitigation technologies[27–29].

3.3 Socio-Economic Disruption: The Human Toll

3.3.1 Displacement and Livelihood Disruption

Coal mining has historically played a significant role in extensive land dispossession, particularly affecting adivasi (tribal) and rural communities residing in resource-rich regions of India. These communities, traditionally dependent on land and surrounding forests for their livelihoods, frequently experience the loss of long-standing agrarian subsistence[30]. Empirical evidence from a comprehensive study conducted in Talcher illustrates this phenomenon, revealing a dramatic decline in the percentage of the workforce engaged in cultivation activities from 68.30% in 1981 to a mere 6.4% by 2011, indicating a profound transformation in the local economic landscape[30]. Although the mining sector has significantly contributed to national economic development, it is crucial to acknowledge that the benefits of this growth have not been equitably distributed at the local level, where poverty remains pervasive. This disparity underscores the urgent need for a more inclusive approach to resource management that considers the rights and needs of marginalized communities disproportionately affected by extractive industries. In conclusion, although coal mining may offer short-term economic gains at the national level, it simultaneously exacerbates social inequalities and undermines the traditional livelihoods of vulnerable populations, necessitating a critical reassessment of policies governing resource extraction in India[17].

3.3.2 The Creation of Internal Inequality

One significant yet frequently overlooked consequence of mining activities is the pronounced emergence of social stratification within local communities, which fundamentally alters the dynamics of social interactions and relationships. Policies designed to provide compensation and relief to those adversely affected have, in numerous instances, led to a paradoxical situation in which the intended benefits inadvertently contribute to the degradation of communal solidarity and cohesion among community members. For instance, in a specific village located in Karampot, Jharkhand, the implementation of an inadequately structured compensation policy resulted

in a scenario in which only a subset of displaced Adivasi villagers was afforded employment opportunities, while a considerable number of others were rendered ineligible for any form of compensatory work because their land had not yet been formally acquired through mining. As a direct consequence of this disparity, stark and pronounced contrasts in living conditions have emerged within the communities. Those fortunate enough to gain employment began constructing modern concrete houses and acquiring motorcycles, whereas their less fortunate counterparts found themselves relegated to living in primitive mud dwellings and resorting to precarious and often illicit means of livelihood, such as coal peddling, to survive. This unequal and inequitable distribution of economic benefits not only disrupts but also systematically dismantles the traditional practices of mutual labor exchange and cooperative support that have historically underpinned the social fabric of the community, thereby replacing a once harmonious and egalitarian social structure with new and insidious forms of inequality, resentment, and social discord. Ultimately, the ramifications of such policies extend far beyond mere economic considerations, fundamentally challenging the essence of community identity and solidarity, which are essential for the collective well-being and social stability of the affected population. Considering these observations, policymakers and stakeholders must critically assess the broader implications of compensation strategies to mitigate their adverse effects on social cohesion and reinforce community solidarity in the face of disruptive economic changes[31].

3.3.3 Public Health Crisis in Mining Regions

Environmental degradation resulting from mining activities has profound implications for public health and must be thoroughly considered in any comprehensive analysis. Extensive research conducted in various regions, including the Tamnar area in Chhattisgarh, has demonstrated that local populations, particularly marginalized tribal communities, are at an increased risk of contracting acute respiratory diseases and tuberculosis, which is directly linked to the proximity of mining operations[32]. Alarmingly, the incidence of tuberculosis in Tamnar is reported to be nearly double the national average, a concerning statistic attributed to factors such as air pollution, contamination of local water sources, and the overall poor living conditions in these areas. Furthermore, individuals employed in mines face significant occupational hazards, as they are at risk of developing serious respiratory illnesses, including pneumoconiosis, various forms of asthma, and chronic obstructive pulmonary diseases, all of which result from the inhalation of harmful coal dust particles[33]. This public health crisis, intricately linked to environmental deterioration, transcends ecological concerns and manifests profound and complex socioeconomic challenges. A comprehensive review of the data revealed alarmingly high rates of malnutrition and entrenched poverty that further compound the health risks faced by these communities, thereby creating a vicious cycle of illness and deprivation that is exceedingly difficult to break. In light of these findings, it is imperative to adopt a multifaceted approach to address not only the environmental issues stemming from mining but also the underlying socioeconomic factors contributing to public health challenges faced by these vulnerable populations. Ultimately, a holistic understanding of the interplay between environmental degradation and public health is essential for developing effective policies and interventions to mitigate adverse effects and promote the well-being of affected communities[16,34].

3.4 Capacity Building: A Missing Pillar

There should be major emphasis on capacity building. The industry should be encouraged to open mining and mineral institutes (e.g., Indian Institute of Mining & Mineral Sciences, IIT-ISM Dhanbad model expanded to coal belts). Also: retraining of workers for solar/wind installation, green hydrogen, and mine reclamation; encouraging local banking and insurance sectors to offer transition loans and micro-insurance for ex-miners; local education (ITIs in mining districts to shift to RE vocational training); local health prospects (upgrading district hospitals in coal belts for respiratory diseases). Without capacity building, a just transition remains rhetorical.

3.5 Legal Framework and Institution Building with Social Justice

The legal framework should mandate a National Just Transition Authority (analogous to South Africa's PJT)

under the Environment (Protection) Act, 1986. Institution building should include: (i) District-level Just Transition Funds (JTFs) financed by coal cess; (ii) Social justice focus through compensatory affirmative action for displaced tribal communities (restoration of forest rights under FRA, 2006); (iii) Legal right to retraining and alternative employment for all permanently displaced worker.

4.0 The Dynamics of India's Energy Transition

4.1 National Commitments and Policy Frameworks

India's national energy policy has been meticulously crafted to align with its broader commitment to global climate change mitigation and sustainability. The nation has formally committed to a substantial reduction in the intensity of its greenhouse gas emissions relative to its Gross Domestic Product (GDP), aiming for a 45% decrease from the baseline level established in 2005. Furthermore, by 2030, India aspires to ensure that 50% of its total cumulative installed electric power capacity is sourced from renewable, non-fossil fuel sources, marking a significant milestone in achieving net-zero emissions by 2070[13,15,35]. This ambitious energy transition is spearheaded by the Ministry of New and Renewable Energy (MNRE), which is at the forefront of implementing a comprehensive suite of flagship initiatives to catalyze change. Among these initiatives is the PM Surya Ghar: Muft Bijli Yojana, a program that provides substantial financial subsidies to facilitate the installation of rooftop solar panels in one million households, thereby promoting the widespread adoption of solar energy in India. Additionally, the PM-KUSUM scheme was designed to assist agricultural stakeholders by enabling the solarization of irrigation pumps, thereby integrating renewable energy solutions into the farming sector in India. Moreover, the government's Solar Parks Scheme aims to establish large-scale solar power generation facilities with the objective of achieving a capacity of 40 gigawatts (GW) by March 2026, thereby contributing significantly to the nation's clean energy goals[36]. Collectively, these initiatives exemplify India's commitment to a sustainable energy future, addressing both domestic energy needs and international climate obligations while fostering economic growth and resilience through innovative approaches to renewable energy development[6,19,37,38].

Table 4. Comparative energy transition policy framework (EU, USA, UK and SA)

Country	Coal Phase-out Target	Just Transition Mechanism	Key Policy Instrument	Relevance to India
EU (Germany)	2038	€40 billion commission + regional structural funds	Coal exit law, compensation for workers/regions	Learn: legally binding timelines + dedicated fund
USA (Justice40)	No national ban; market-driven	Justice40 Initiative – 40% benefits to disadvantaged communities	IRA tax credits, POWER+ grants	Learn: targeted community benefits
UK	2024 (achieved)	Task Force for Just Transition (Scotland)	CfD auctions, coal worker retraining	Learn: early consultation with unions
South Africa	2030-2035	Presidential Climate Commission – Just Transition Framework	Just Energy Transition Investment Plan (JET-IP, $8.5 bn)	Learn: international climate finance for coal-dependent regions
India (proposed)	2050-2055 (no formal date)	None yet – proposed National JTA	Need: Coal cess to JTF, retraining bonds	This study recommends adoption of hybrid SA+Germany model

Table 5. Policy gaps and recomended action for India

Area	Current Status	Gap	Recommendation
Coal block allocation	PSUs retain good deposits	Private sector complaint	Independent geological certification before auction
Just Transition	No formal policy	1.4 million livelihoods at risk	National Just Transition Authority
Retraining	Sporadic programs	No legal entitlement	Workers 'Retraining Entitlement Act
Local banking	No specific products	Ex-miners lack capital	Coal transition micro-loans via RRBs
Comparative learning	No internalised framework	Ad-hoc decisions	Mandatory policy impact assessment using EU/SA models

Table 4 shows the comparative energy transition policy frame work for Eu, USA, UK and South Africa. This comparative framework helps Indian planners balance the EU's legal certainty, USA's community focus, and South Africa's international finance model while avoiding their pitfalls (Germany's high cost, SA's slow disbursal).

Table 5 ouatines the potentiel Policy gaps and recommanded actions for the Indian gouvernement to Cosider.

4.2 Rapid Growth of Renewable Energy

India's transition towards sustainable energy is advancing at an exceptional pace. Recent data reveal that renewable energy sources constitute 50.07% of the nation's total power capacity, which currently stands at 484.82 gigawatts. This milestone was achieved five years ahead of the projected target of 2030. In the first half of 2025, an unprecedented 25.1 gigawatts of renewable capacity was added, primarily driven by solar energy initiatives[36,38]. This substantial increase in renewable energy is already affecting the nation's greenhouse gas emissions. Official government analyses report a 1% reduction in carbon dioxide emissions from the energy sector in the first half of 2025 compared to the same period in the previous year.

This slowdown in emission growth, particularly from the primary contributing sector, suggests that the rapid integration of renewable technologies is fundamentally transforming the nation's energy landscape, even though coal remains a significant component of the energy mix.

As demonstrated in Table 6, the operational capacity of solar energy reached 97.87 GW, while wind and large-scale hydroelectric power contributed 48.16 GW and 52.07 GW, respectively, collectively propelling the country beyond its essential clean energy requirements.

Table 6. Progress Towards India's Non-Fossil Fuel Capacity Target (as of June/July 2025)[36]

Metric	Capacity (GW)
Total Installed Capacity	484.8
Non-Fossil Fuel Capacity	242.8
Share of Non-Fossil Fuel	50.07
Solar Energy Capacity	97.87
Wind Energy Capacity	48.16
Large Hydro Projects	52.07

4.3 The Role of Gas as a Transition Fuel

As India undertakes the intricate task of transitioning its energy landscape towards more sustainable and environmentally friendly sources, natural gas has been identified as a pivotal "bridge" fuel. This fuel can facilitate this transition by providing cleaner and more efficient alternatives to the heavily polluting coal. According to a comprehensive report, natural gas is projected to be the sole fossil fuel experiencing a significant increase in its share in India's overall energy mix by 2050[39]. However, this ambitious vision encounters numerous challenges that must be effectively addressed to achieve the

program's intended outcomes. Regrettably, the nation has "lagged in leveraging gas in the power sector," primarily due to "scalability and commercial challenges" that have impeded the development and integration of natural gas into the existing energy framework. This suggests that the critical transition from traditional coal dependency to a more diversified portfolio of renewable energy sources may largely overlook the potential benefits of a substantial "gas bridge," thereby introducing unique complications in ensuring grid stability and managing the intermittent nature of renewable energy sources. Consequently, it is imperative to evaluate and understand these challenges in depth and devise strategic solutions that can enable the smooth integration of natural gas into the energy matrix to ensure a more reliable and resilient grid system for the future. Overall, the complexities surrounding India's energy transition underscore the necessity of a multifaceted approach that considers both the immediate and long-term implications of various energy sources for national energy security and sustainability[40].

5.0 The "Just Transition": Ensuring Equity in the Shift Away from Coal

5.1 The Human Cost of Decarbonization

Transitioning from an economy predominantly reliant on coal presents a substantial societal challenge, particularly for the extensive workforce associated with the coal industry. The coal sector directly employs approximately 300,000 individuals in permanent positions and an estimated 500,000 in contractual roles[41]. Furthermore, the economic well-being of approximately 1.4 million individuals is intricately linked to coal ecosystems. A concerning trend identified by labor representatives is the persistent reduction in stable and permanent employment, exacerbated by hiring freezes[42,43]. This decline in secure jobs compromises both workers' stability and the collective strength of labor unions. Concurrently, there has been a discernible shift towards employing temporary, low-wage contract workers, undermining established standards for equitable and secure employment[9,44]. The repercussions of these developments extend beyond mere job losses, potentially transforming labor rights and socioeconomic frameworks as energy policies evolve.

populations, such as Dalits, remaining entrenched at the lowest tier of this informal economic hierarchy and facing systemic barriers that perpetuate their marginalization. To facilitate a successful and sustainable transition away from coal reliance, it is imperative to not only focus on creating new job opportunities but also critically address issues of occupational mobility and the necessary structural changes essential for uplifting these marginalized communities. Such an approach necessitates a comprehensive understanding of the underlying socioeconomic factors contributing to their current situation and the development of targeted interventions to effectively break the cycle of dependency on government funding for the homeless. Ultimately, long-term resilience and empowerment can be fostered among those affected by the precariousness of the coal economy through holistic and inclusive strategies. As illustrated in Table 7, the magnitude of dependency is considerable, underscoring the pressing necessity for a strategic transition plan that caters to both direct employment opportunities and the broader community dependent on the coal sector for their livelihood.

Table 7. Coal sector employment and livelihood dependency[41]

Livelihood	Estimated Number
Permanent Workers	300,000
Contract Workers	500,000
Dependent Livelihoods	1.4 million

5.2 Policy Imperatives for a Just Transition

Union representatives have unequivocally advocated for a paradigm shift towards a worker-oriented strategy during the ongoing transition, emphasizing the necessity of fostering robust social dialogue and demanding representation within all committees responsible for planning the transition process. The current instances of abrupt workforce redeployments, coupled with the evident lack of meaningful consultation with labor unions regarding the closure of mining operations, have

emerged as critical issues warranting urgent attention and redress[45].

A thoroughly developed and robust policy framework aimed at facilitating a Just Transition must extend its considerations beyond the limited perspective that solely emphasizes the retraining of employees for new job opportunities. The cessation of operations at coal facilities generates a series of multifaceted repercussions, including not only the immediate loss of employment opportunities for workers but also a significant decline in property values within the surrounding communities and a notable decrease in the revenue collected from local taxes, which is crucial for public services and infrastructure development. Consequently, it is imperative to adopt a comprehensive and integrative approach that encapsulates the three fundamental pillars essential for ensuring a sustainable transition to a circular economy. Relief, reclamation, and reinvestment constitute a triad of strategies aimed at addressing the multifaceted challenges posed by economic downturns and environmental degradation. Relief is primarily concerned with delivering immediate financial and logistical support to individuals and communities that have experienced significant job losses and revenue declines, thereby serving as a crucial safety net during economic crises. In contrast, reclamation focuses on the systematic retooling and repurposing of sites abandoned owing to mining activities, a process that not only generates immediate employment opportunities in both the short- and medium-term but also plays a vital role in mitigating the various environmental risks associated with neglected sites. Finally, the concept of reinvestment is pivotal in cultivating long-term economic resilience and diversification. This entails a strategic shift away from overreliance on a singular industry and aims to develop a new, sustainable economic foundation that effectively encompasses manufacturing, technology, and other burgeoning sectors. This fundamental shift from a narrowly focused, localized labor policy to a more comprehensive approach to regional economic development serves as the cornerstone for achieving a transition that is equitable and sustainable in the long term. By integrating these three elements relief, reclamation, and reinvestment policymakers can create a holistic framework that simultaneously fosters community revitalization and environmental stewardship. Such an approach ensures that the transition towards a more diversified economy does not merely address immediate concerns but also lays the groundwork for a sustainable future that benefits all stakeholders involved.

6.0 Conclusion

India's energy strategy is characterized by a significant dual focus on the simultaneous expansion of both coal and renewable energy infrastructure. This dual approach represents a pragmatic yet challenging method for meeting the increasing energy demands of the nation. However, reliance on coal is accompanied by substantial environmental and social challenges, including deforestation, land degradation, health issues, and community displacement, which are significant obstacles that must be addressed. Although the rapid growth of renewable energy is a positive development that contributes to emission reductions, a comprehensive plan for a "Just Transition" is essential for sustainable progress. Millions of individuals associated with the coal industry require a well-conceived policy that extends beyond mere worker retraining; it should also encompass immediate support for affected communities, land restoration, and investment to diversify local economies. To secure its energy future, India must balance energy security with environmental stewardship and social justice, ensuring that the path to development and achieving net-zero emissions is robust and inclusive.

7.0 Declarations

7.1 Availability of Data and Materials

The datasets analyzed in the current study were derived from publicly accessible sources, including the Ministry of Coal annual reports and press releases, Coal India Limited's Integrated Annual Report 2024–25, and peer-reviewed publications cited in the references. These are fully described in this manuscript. Supplementary data or raw extracts can be obtained from the corresponding author upon reasonable requests.

7.2 Competing Interests

The authors declare no competing financial or nonfinancial interests. Although the authors are employed by Coal India Limited, their affiliations do not influence the

objective analysis or conclusions presented in this study. The views expressed are personal and do not represent the official positions of Coal India Limited or any other entity.

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Author Contribution

Vikram S. Parihar contributed to the conceptualization, methodology, formal analysis, data curation, and writing of the original draft. Bidya Nath Jha contributed to validation, investigation, resources, and writing—review and editing. Both authors contributed to the visualization, project administration, and approval of the final manuscript.

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