CENTRE FOR A People-centric Energy Transition

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Viksit Bharat @ 2047 Goal may pause Coal Phase Down in India: An opportunity for People Centricity in transition

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Abstract:

India aims to reach Viksit Bharat status by 2047 and a Net Zero Economy by 2070. This would require annual GDP growth averaging between 7% - 9% and renewable energy share in electricity generation increasing from 14 % to 60% by 2047 and beyond. Another target is increasing the share of Manufacturing in GDP, from 27% to 35%. With this premise, this paper creates a macroeconomic framework of various Manufacturing sector growth scenarios, along with a rise in renewable energy share in the generation mix. The scenario-based empirical framework, backed by an econometric regression and ML model, shows that coal-based (steam) electricity generation, by 2047, can increase threefold compared to 2025, driven by rising demand from Manufacturing @35% of GDP and Services @58%, of GDP, growing at a rate of at least 7% p.a. For attaining Net Zero emissions by 2070, it is imperative that renewable energy's share in electricity generation increases to at least 60% by 2047. Our model reflects a possibility of coal phase down, beyond 2047, as renewable energy share crosses more than 70% in generation, towards 2070, with adequate storage to meet round-the-clock and peak demand.

Such a coal phase-down will most directly impact the 221 districts of India, having multiple assets and livelihoods tied to coal mines, affecting 13 million direct and indirect jobs. PSUs like Coal India Limited (including subsidiaries) and NLC India Limited, which create jobs for 369,053 individuals, including 128,236 contractual workers will therefore need to adopt timely socio-economic security nets, reskilling, upskilling, and rehabilitation measures backed by the Central and State Governments in order to ensure socio-economic inclusion is not compromised and India's Viksit Bharat and Net Zero Goals do not stay in a dialectical relationship in the future.

Keywords: Net Zero, Viksit Bharat, Thermal Coal Demand, Social Impacts, ML Econometric Model, Phase Down Delay, Rehabilitation, Socio-Economic Security

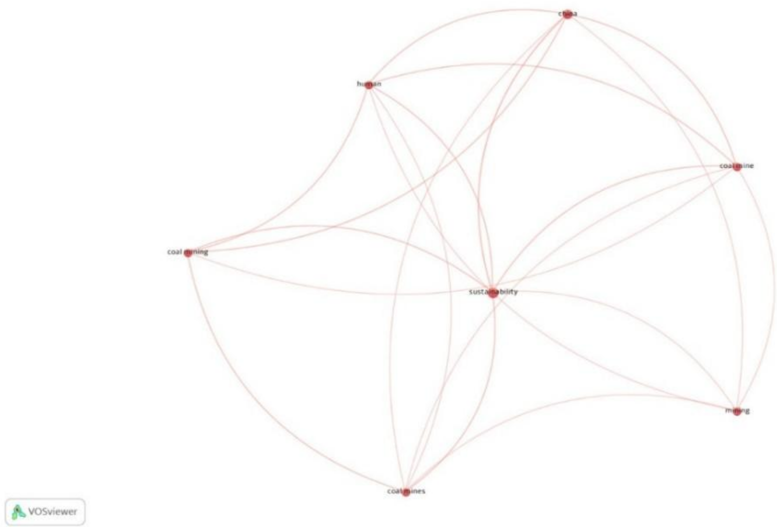
1. Introduction

Coal, continues to play a dominant role in India's energy mix, contributing over 70% of India's electricity generation. Energy and development have always had a close interplay. Aspiring to become a high-income country by 2047 (World Bank, 2024), India has set out on a path of rapid economic development, which will directly increase energy demand of the country. Under the Viksit Bharat Vision goal of 2047, the country has set an ambitious target of becoming a $30 trillion economy (NITI Aayog, 2024). Furthermore, under the Net Zero @2070 initiative, India aims to transition to primarily clean sources, for electricity generation. Attainment of both goals would require sustaining average annual GDP growth of at least 7% for the next 2 decades, with, rapid infrastructural changes in the energy landscape.

This much required development pace, juxtaposed with targeted carbon neutrality, raises a critical set of questions: Can the growth in renewable capacity and generation keep pace with the surge in energy demand in India, on the Viksit Bharat @2047 and Net Zero Goal by 2070 path? Further, if India has to attain the Viksit Bharat Goals of 2047, along with its ambitious plans of 'phasing down' the use of coal by 2050 and being a carbon-neutral economy by 2070 (Kripal Singh, 2023) what will be the required installed capacities for both coal and renewables? This paper attempts to answer these questions through a structured, multi-step quantitative, mixed-method framework integrated with ML based forecasting model, with an estimation of sector-wise electricity demand. The paper further explores the implications of the sector-wise electricity demand on coal demand (thermal), as well as renewable energy capacity needs.

2. Literature Review and Relevance:

The global coal demand is still on the rise. In 2024, the world witnessed 1.2% rise, equivalent to an increase of approximately 67 million tonnes of coal equivalent (Mtoe) in energy terms. (IEA, 2025).



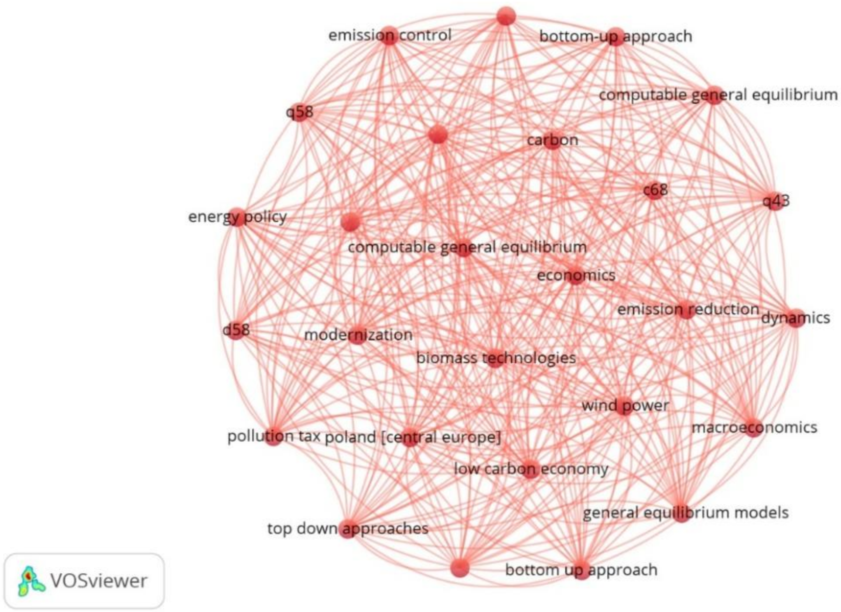


Figure 1 Bibliometric Analysis

From the bibliometric analysis of the literature, it emerges that, macroeconomic studies dealing with coal phase down, have mostly adopted a computable general equilibrium approach, for explaining the impacts of coal phase down on the economy. The global and local literature also highlight, that the basic essence of coal phase down is driven by the need to move towards the path of decarbonization, carbon emission reduction and low carbon economy priorities.

The global literature also indicates the primacy of new low carbon energy policies, in measures to address decarbonization, leading to the discussion on coal phase down. The alternatives being discussed as a substitute for coal, are largely – wind, solar and biomass technologies. The bibliometric analysis using network effects, clearly reflects this pattern. The literature also indicates that the path and decision of coal phase down is being determined by pollution control policies, energy policies and the larger macroeconomic considerations of coal phase down. Within the literature discourse from developed countries, it emerges that, often, the decision of coal phase down is also being determined by the core agenda of economic, environmental, governance domains of sustainability which drives the centrality and core agenda of coal phase down as a part of people centric energy transition measures all across the world.

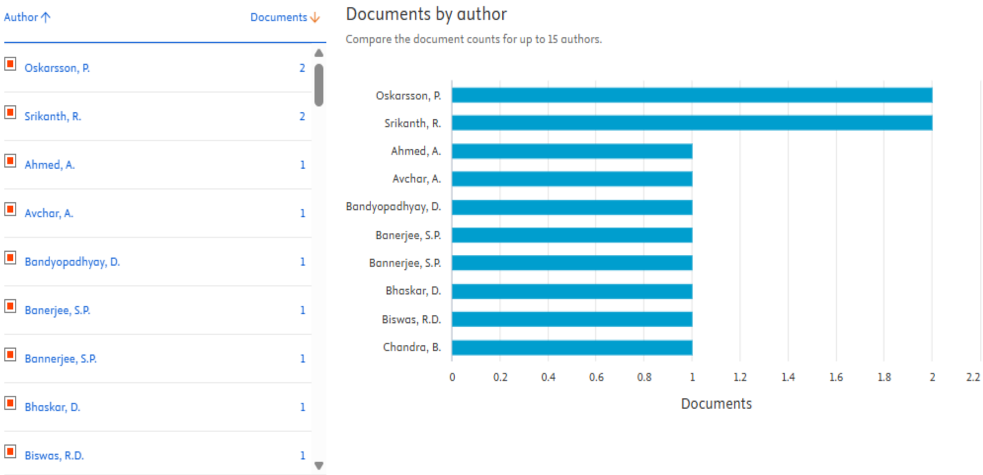
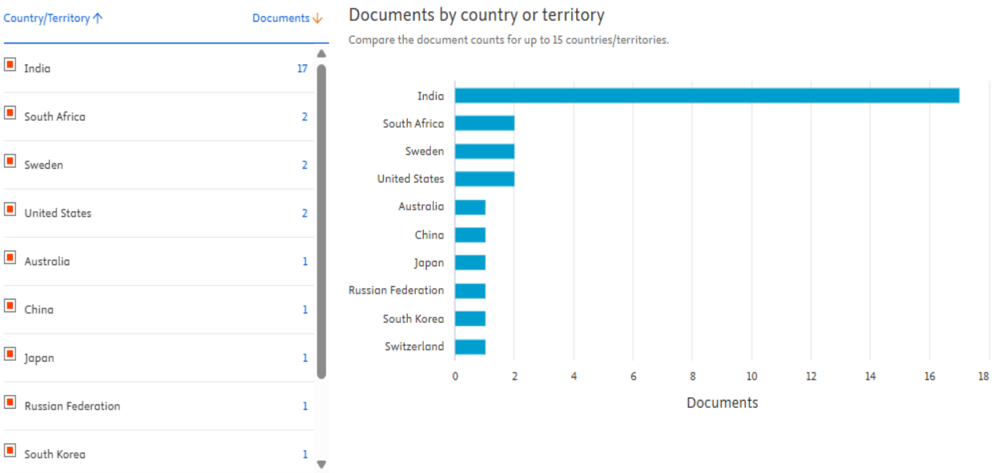


Figure 3 Author wise distribution of literature on coal phase down



Ec*Figure 4 Country Wise Distribution of Literature on Coal Phase Down*

Figure 2 Discipline Wise Distribution of Literature on Coal Phase Down

Results of global literature review conducted from 1975 to 2025 on coal phase down and macroeconomic impacts reflects in Figures 2,3,4. Our global literature review of coal phase down from 448 best cited papers (Refer to Annexure III) of Scopus indicates that most papers are from India and belong to the domains of Social Science, Energy, Environmental Sciences, Earth and Planetary Sciences. From the literature it evolves that macro-economic impacts of coal phase down of India is an important area of academic investigation.

The electricity sector of India remains the dominant driver of its coal demand within India, accounting for more than two-thirds of coal consumption. It is thus essential to study the future trajectory of power sector in an integrated manner, along with the performance of various sectors of the economy, to understand how coal demand will change, while being in sync with the possible socioeconomic implications of the sector owing to a coal phase down.

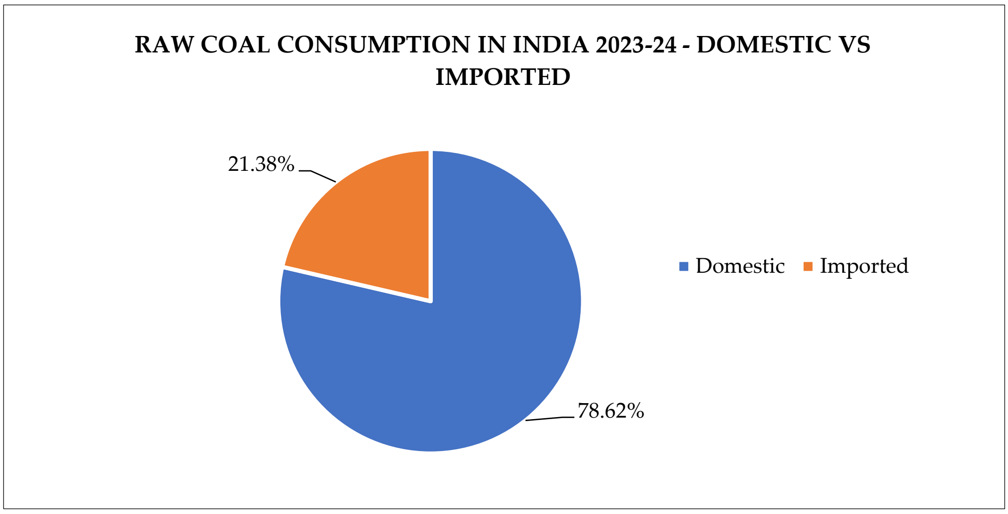


Figure 5 Raw coal consumption: Imported vs domestic

Especially in the case of India, where power generation predominantly relies on domestically produced non-coking coal (MoC, 2023-24)), studying future coal demand becomes all the more essential—not just for ensuring energy security, but also due to the significant socio-economic implications, with a large workforce being dependent on the coal sector. India consumed a total of 1237.54 million tonnes (Mt)[1]of coal in 2023–24. Coal consumption saw a record increase of 10.9 %1 between 2022–23 and 2023–24. The power sector alone accounts for over 70% of total coal use (CEA, 2024).

Given the predominant role of the power sector in driving overall coal demand, this study focuses exclusively on thermal coal by analysing it in detail. The demand for non-thermal coal which is used mostly for the steel, cement and other industries lies outside the scope of this analysis. Broadly, the categorisation of the coal for this study can be seen as follows in Figure 6 –

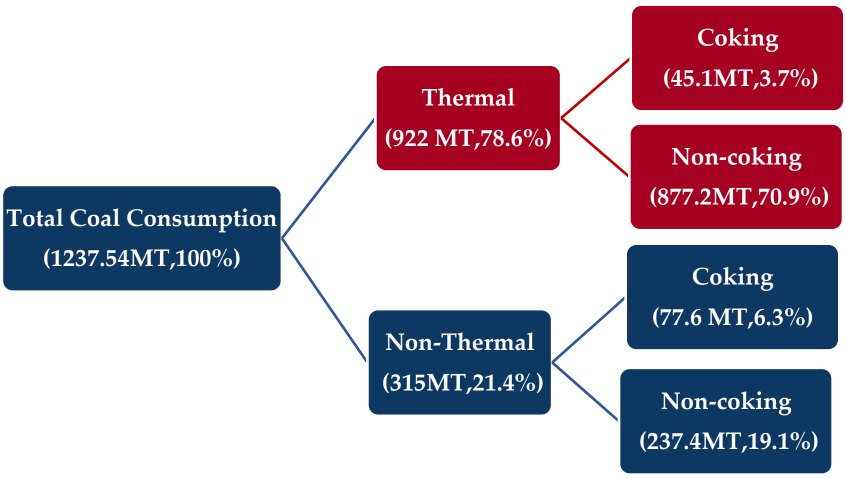


Figure 5 Categorisation of Coal

3. *Research Gap and Innovative Contribution of the Paper*

[1] Coal directory 2023-24

The goals of Viksit Bharat and achieving net-zero emissions represent two intertwined yet challenging objectives—economic and environmental. On one hand, India aspires to become a rapidly growing economy, and on the other, it envisions a transition towards clean energy. While both transitions are expected to unfold simultaneously, the complex interplay between them has not been fully evaluated, particularly in the Indian context.

Presently, over 78% (MOSPI, 2025) of electricity consumed by end users in India is generated from coal, while renewable energy (RE) contributes only about 12% (CEA, 2024). Although the share of RE in the generation mix is expected to grow in the coming decades, the pace of this transition remains uncertain.

The Central Electricity Authority (CEA), in its recent report, has projected electricity demand to reach approximately 2473.7 billion units (BU), which is nearly 1.7 times the current electricity consumption by 2030, merely 5 years from now. Increased per capita income, urbanisation, domestic manufacturing, automation, electric mobility, Data centres and GCCs with AI integration, etc., will strengthen the role of electricity as the backbone of India's energy ecosystem. Commercial and industrial sectors consume 48.5% and 19% (IEA, 2025) of their total energy in the form of electricity, respectively. In contrast, transport sector continues to rely heavily on oil, with 89% (IEA, 2025) of its energy needs met through petroleum products.

Given the future rise in sectoral electricity demand, critical issues like intermittency, the role of battery storage, and the complementary use of coal and renewables have been widely debated in the literature. However, there is a shortage of realistic and empirically grounded, scenario-based analyses on how electricity demand, installed capacity of coal and RES, along with coal and RES-based share, will grow for different scenarios of Viksit Bharat based industry, services, and agricultural share growth of the Indian Economy.

This study employs a regression-based approach to analyse the key drivers of electricity demand growth. While regression methods backed by robustness tests are less commonly used in this context, they offer a crucial advantage: simplicity and transparency in modelling, enabling analysts to rapidly capture the impact of structural economic shifts—such as changes in sectoral composition—on electricity demand (Jebaraj & Iniyan, 2006; Bhattacharyya & Timilsina, 2010). Although regression models can face challenges such as endogeneity and omitted variable bias (Wooldridge, 2010; Greene, 2012), they provide a valuable, high-level 'bird's-eye view' of the economy, which is especially useful for policy analysis and preliminary scenario exploration (Bhattacharyya & Timilsina, 2010).

By conducting sensitivity analyses, this approach can yield insights that are both realistic and directly policy-relevant, thereby supporting India's energy transition and development goals. The modelling approach is not based on operational system constraints or explicit causality, system optimization but on a mixed method based, regression framework backed by post estimation robustness tests based on statistical and ML methods.

4. Research Methodology

The methodological framework imbibes a scenario-based thermal coal demand modelling. This paper utilizes an Excel-based model to project the demand for thermal coal in the context of GDP growth and electricity demand. The modelling approach focuses on the following research questions -

(i) How does the growth of GDP drive demand for thermal coal-based electricity and demand for coal, given the Viksit Bharat @2047 and Net Zero @2070 goals?

(ii) How do changes in sectoral share of Agriculture, Manufacturing (Industry), and Services in an expanding GDP, under Viksit Bharat trajectory and Net Zero @2070, impact thermal coal-based electricity and coal demand in future, across multiple scenarios?

(iii) How does the growth of clean energy sources (Renewables-solar, wind) in electricity generation mix under Net Zero @2070 trajectory, impact the demand for thermal coal, as India seeks to meet required sectoral electricity demand, on the Viksit Bharat Growth Path.

The analysis examines 12 scenarios from pairing three industrial growth trajectories with four electricity generation mixes. Manufacturing's Share in GDP increases to 27%,30% and 34.5% by 2047, forming low, medium, and high growth scenarios reflecting 'Make in India' ambitions.

Each industrial growth scenario combines with four renewable energy scenarios—low, conservative, desirable, and optimistic—representing different levels of RES penetration and coal dependence. This comprehensive matrix examines how economic shifts and energy transitions jointly influence electricity demand and capacity requirements for meeting Viksit Bharat 2047 and Net Zero 2070 targets. Causal regression measures how sensitive electricity demand is to economic changes across sectors.

Table 1 Sectoral GDP share scenario

Sector share in GDP				
Year	Scenarios (Manufacturing Share in GDP)	Agriculture	Manufacturing	Services
2022-23[2]		15.3%	21.4%	63.3%
2046-47	Low	10.0%	27.0%	63.0%
2046-47	Medium	10.0%	30.0%	60.0%
2046-47	High	6.8%	34.5%	58.7%

Table 2 Energy mix pathways

Sector share in Electricity Generation				
Year	Scenarios	Steam	RES	Others
2022-23	Actual (as of 2024)	74%	12%	14%
2046-47	Low-RES growth	70%	15%	15%
2046-47	Conservative-RES growth	65%	20%	15%
2046-47	Desirable -RES growth	35%	50%	15%
2046-47	Optimistic -RES growth	25%	60%	15%

The model relies on certain core assumptions:

- GDP is projected to grow at an annual rate of 7% until 2047.
- Base year for the study is 2022-23.

[2] Source for base year data is RBI data base

- The share of the services sector in GDP is assumed to remain more or less constant throughout the projection period.
- Any increase in the industrial sector's share in GDP is mostly offset by a corresponding decrease in the agriculture sector's share, ensuring the total adds up to 100%.
- Sectoral electricity demand is assumed to be proportional to the respective sector's share in GDP.
- RES covers -renewable energy sources comprising wind, solar, small hydro, bio-mass, excluding large hydro. Solar and wind energy are expected to continue current trend of faster growth in RES generation, during the study period.
- A combined share of Nuclear and Large Hydro at 15% of total electricity generation mix, is retained till 2047.
- The CUF improves over time for all RES sources.
- Auxiliary Consumption and T&D losses reduce over time.
- The industry sector share changes from 27% (Low), 30% (medium) to 34.5% (high) in the Viksit Bharat 2047 and Net Zero Growth Path of 2070
- Sectors become energy efficient over time; thus, electricity demand increases at a decreasing rate.
- An additional upper bound scenario of RES (Renewable Energy Share) is chosen to understand at what level, coal phasing down actually happens

For each scenario, projections are generated and validated against credible external datasets and planning documents such as NITI Aayog's IESS model V3, MNRE projected targets for RE, CEA forecasting for electricity demand etc. The datasets utilised in the study are mentioned in Annexure 2 along with literature in Annexure 3. These projections help evaluate how India's coal and renewable energy needs are likely to evolve, particularly in balancing economic growth with the imperative of decarbonization.

4.1Framework and Process Workflow:

The model framework and process workflow are as follows (Fig. 7) -

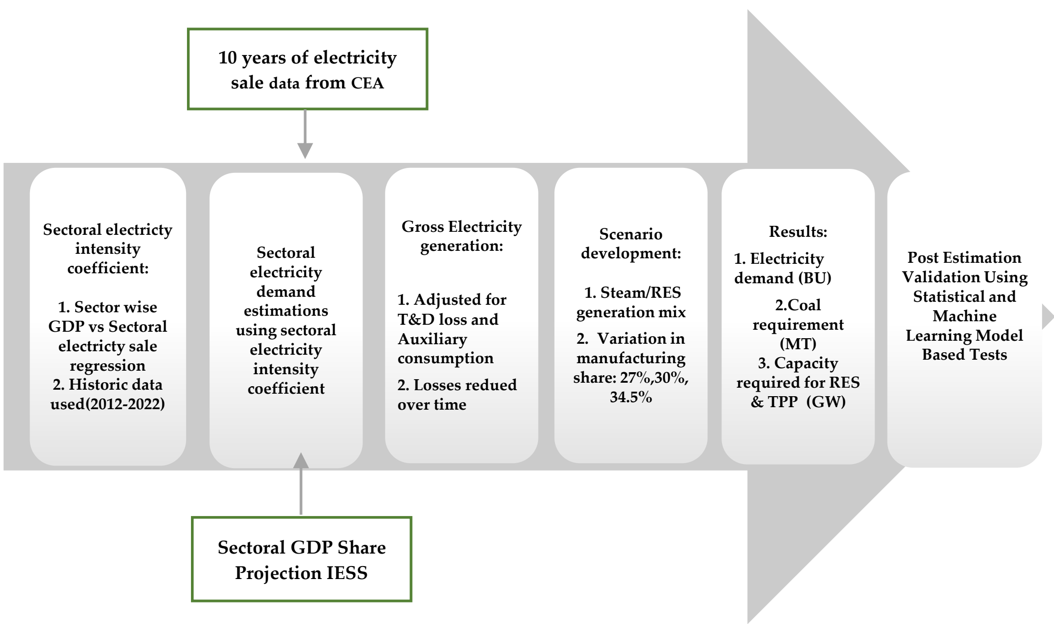


Figure 7 Workflow of the model

Furthermore, the robustness of future projections are, also, tested using a Post Estimation Statistical Tests, Machine Learning (ML) algorithm to measure the precision of the model's projection results by reducing the errors in the model projections through training with an ML model structure.

The estimation process of the model is explained below –

4.2 Thermal Coal Demand Evaluation:

Thermal coal demand is estimated based on electricity generation patterns. For each energy mix scenario, the proportion of electricity generated from steam-based (coal-fired) sources is identified. This share is then used to calculate the corresponding thermal coal requirement for a given year. The following steps are undertaken to arrive at the final estimate of thermal coal demand:

4.2.1 Estimation of Sectoral Share in GDP

Projected sectoral share in GDP till 2047 is sourced and validated from the India Energy Security Scenarios (IESS) framework of Niti Aayog, which provides consistent long-term economic forecasts aligned with national policy objectives. NITI AAYOG's IESS V3 2047 (published in 2023) includes a Medium GDP Growth trajectory- assumes 7% CAGR from 2022 to 2047. GDP projections from IESS are retained and are adjusted for different sectoral composition by modifying the share of manufacturing (industry), agriculture, and services as per alternate growth scenarios -low, medium & high.

4.2.1 Sector-wise Electricity Demand Estimation

The relationship between sectoral growth and electricity demand is established using regression analysis between electricity sales to sectors and sectoral GVA figures using historic data for the last ten years. Sectoral electricity sales data is taken from the CEA reviews, and Sectoral GVA figures are taken from the RBI database for the years 2012-2022. A regression analysis is conducted to quantify how changes in the sector's economic output in the previous year influence its electricity consumption in the present year. Regression equation is as follows,

$$\mathbf{Electricity\_Sales_t = \alpha + \beta \cdot GVA_{t-1} + \varepsilon_t}$$

Where:

- $Electricity\_Sales_t$: is the electricity consumption in year *t*,
- GVA_{t-1} is the Gross Value Added of the sector in the previous year (*t–1*),
- A is the intercept,
- β is the regression coefficient,
- ε_t is the error term.

The fundamental assumption behind the above equation framework is that the last period economic activity of the sector provides a signal for the dispatch decision in the next period, which decides the electricity sales of the next period. To minimize concerns of reverse causality, this study uses a one-year lag of GVA as an explanatory variable(Wooldridge, 2010).

The resulting regression coefficients, interpreted as elasticities, represent the electricity intensity of each sector. These elasticities serve as sector-specific multipliers, allowing us to estimate how electricity demand will evolve in response to the sector's economic output till 2047. The results of the regression analysis are summarised below:

Table 3 Regression coefficients

Sector	Elasticity
Agriculture, Forestry & Fishing	0.12
Industry	0.16
Services	0.06

The industry sector exhibits the highest elasticity (0.16). This reflects the energy-intensive nature of industrial activities. The agriculture, forestry, and fishing sector has a moderate elasticity of 0.12, indicating a modest response of electricity demand to economic growth in this sector, possibly influenced by mechanisation and irrigation practices. The services sector exhibits the lowest elasticity (0.06), which is consistent with the sector's relatively low energy intensity and the dominant role of human capital over physical infrastructure in service-based activities, as well as its nearly constant share of the GDP growth path. These elasticity estimates are used in projecting future electricity demand across sectors based on projected economic growth trajectories.

4.2.3 Gross Electricity Generation Estimation

Gross electricity generation includes transmission and distribution (T&D) losses as well as auxiliary consumption within power plants. Therefore, to estimate gross generation from final electricity sales to sectors, system-level inefficiencies had to be accounted for. Hence, we further incorporated transmission and distribution (T&D) loss and an auxiliary consumption rate, which improves gradually in the Viksit Bharat Growth Path trajectory. We have also incorporated a gradual efficiency improvement of 5% in gross electricity generation over the analysis period. This adjustment is based on the assumption that economic sectors will become more energy-efficient over time, thereby requiring less electricity per unit of economic output. The 5% efficiency gain is a conservative estimate derived from historical trends—over the past decade, India's GDP has grown approximately 5.8%[3] more efficiently with respect to energy consumption. This suggests a decoupling trend between energy demand and economic growth, which the model scenarios attempt to reflect.

Table 4 Assumption for improvement in Auxiliary and T&D losses

	Auxiliary consumption	T&D loss
2020-21	5.8%	15.8%

The rationale behind including these adjustments is to align demand-side estimates with supply-side planning - that is, to determine how much gross electricity needs to be generated to meet sectoral demand after accounting for system losses and auxiliary consumption.

4.2.4 *Estimation of Thermal coal demand*

Once the gross electricity generation for a given year is estimated, the demand for thermal coal can be derived based on the share of electricity generated from steam-based power plants for each energy mix scenario. By applying the projected share of

[3] Author's calculation

the steam, RES, and others[4] on gross generation, we get generation by thermal power plants and RES (in BU). Using the generation of electricity by TPPs, we calculated the respective demand for coal using a fixed conversion factor of 0.6035 Kg of coal per kWh of electricity generated. This coal demand includes the imported coal along with domestic thermal coal consumed by coal-based TPPs.

4.7 *Capacity Estimation- Renewable Energy Sources (RES) and Coal*

To determine the installed capacity required to support the projected generation, the capacity requirement was calculated separately for coal and RES, given the generation.

The total generation attributed to RES from gross electricity generated in each scenario was further disaggregated among solar, wind, biomass, and small hydro in proportion to their 2024 shares. These source-wise shares were varied over the years to make solar dominant by 2047 as India has achieved massive success through solar energy after COP21 and 80% of future investments are for solar energy (Kripal Singh, 2023). Solar is followed by wind, and this assumption is in line with RE policy targets (PIB, 2024). The variation in share is mentioned in table 5 below,

Table 5 - Percentage share in generation source wise for RES (the others share which includes nuclear cannot be zero – hence this table is wrong)

% share in RES generation					
	Small Hydro power	Wind Power	Bio Power	Solar Power	Total RES Share (%) in generation
2023-24	4%	37%	8%	51%	12%(RES) 74%(Coal) 14%(Others)
2046-47	5%	30%	5%	60%	60% (RES), 25 % (Coal), 15% (Others
2046 -47 (Upper Bound Scenario of Phase Down)	5%	30%	5%	60%	70% (RES), 15% (Coal), 15% (Others)

 # Varying share of Steam and RES. Balance 15% of generation is expected from Large Hydro/ Nuclear

To estimate the required installed capacity for each renewable energy (RE) source, conversion factors were derived based on the generation-to-capacity6 relationship for each source. These factors account for improvements in the Capacity Utilisation Factor (CUF), as assumed in Table 6 below. These factors were then applied to the total projected RE generation, using the share of each source in the RE generation mix, to determine the source-wise capacity requirements, which are aggregated to get total RE capacity.

Table 6 Improvement in CUF for RES sources

	CUF			
Year	Small Hydro power	Wind Power	Bio Power	Solar Power
2022-23	26%	19%	20%	17%
2046-47	30%	38%	28%	40%

[4] CEA categorize source wise generation as RES, Hydro, Steam, Diesel, Gas. We define generation from others as summation of generation from Diesel, gas and hydro

[5] Calculated in Appendix C

[6] The factor is Calculated in Appendix C

Similarly, coal capacity was estimated using coal's projected share in the generation mix and 2024 generation-capacity ratios6. For steam-based generation, the generation-to-capacity is considered to remain constant till 2047. These are mature technologies with limited scope for efficiency improvement. Additionally, their role in balancing variable renewables and policy constraints is expected to keep their capacity utilisation largely stable over time. The outcome was a set of twelve projected capacity requirements for both RE and coal, corresponding to the twelve scenarios.

The capacity estimation of both RES and coal under various scenarios helps evaluate the scale and direction of infrastructure changes required to meet different policy goals. It highlights potential trade-offs between coal reliance and RE deployment, while also flagging the risks if energy mix does not evolve in tandem with economic development needs.

5. Results and Analysis

The following results allows for a granular and policy-sensitive analysis of India's energy future, providing adaptable insights to both national planning efforts and sector-specific strategy formulation. These outcomes provide a forward-looking assessment of India's energy landscape in 2047, aligned with the Viksit Bharat vision.

5.1 *Thermal coal Demand:*

This study empirically demonstrates that India's coal demand is set to rise in absolute terms until at least 2047, regardless of the expansion in renewable energy (RE) generation capacity. Even in a scenario where 60% of electricity comes from renewable sources, thermal power plants (TPPs) are projected to consume around 1,283 million tonnes (Mt) coal, if manufacturing share grows to 34.5% of GDP, and approximately 1,221 Mt if manufacturing share accounts for just 27% of GDP. Both figures exceed the thermal coal consumption level in 2024, which stood at 922.38 Mt.

While coal demand may plateau in high-RES generation scenarios, these are highly ambitious pathways that hinge on the rapid development and deployment of advanced battery storage systems—something that remains a technological and economic challenge. In a boundary scenario of extremely high RES share in the generation mix of around 70%, with coal being 15% and others (Large Hydro/Nuclear), being 15%, coal phase down starts to happen with the coal demand phasing down to 700 million tonnes beyond 2047. In such a scenario, however, nuclear has to reach its targeted 100 GW capacity, and gas also has to reach more than 10% of the generation mix and move closer towards 15% of the energy generation mix.

In a more realistic scenario, where coal-based power continues to contribute roughly 55% of electricity generation, thermal coal demand could surge to 2687 Mt and 2 Mt under high and low industrial growth scenarios respectively—more than double the current consumption. This reinforces a critical insight: although the growth rate of coal demand may slow due to increasing RES penetration, in absolute terms, thermal coal demand is likely to keep rising until 2047.

Table 7 Projected demand of thermal coal

	Projected Demand for Coal for electricity generation in 2047(Million tonnes)			
	Variation in electricity generation mix#			
Share of Manufacturing GVA in GDP	Low growth in RES (Coal: 70%, RES 15%)	Conservative growth in RES (Coal:55%, RES:30%)	Desirable growth in RES (Coal: 35%, RES:50%)	Optimistic Growth in RES (Coal: 25%, RES:60%)

Low (27%)	**3420**	**2687**	**1710**	**1221**
Medium (30%)	**3517**	**2763**	**1758**	**1256**
High (34.5%)	**3593**	**2823**	**1797**	**1283**

 # Varying share of Steam and RES. Balance 15% of generation is expected from Large Hydro/ Nuclear

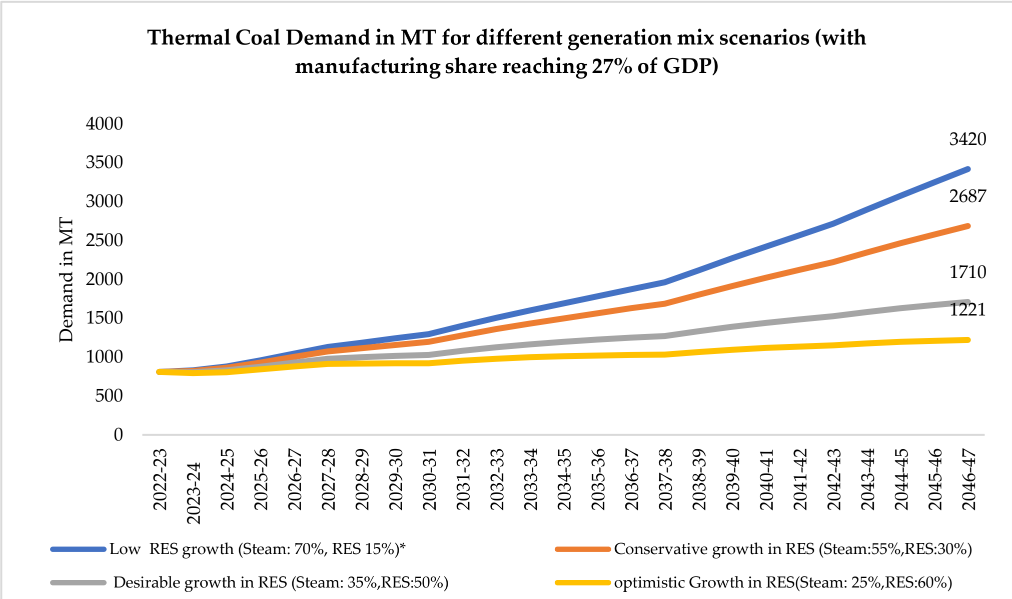


Figure 8 Demand for Coal when the share of manufacturing grows to 27% of GDP in 2047

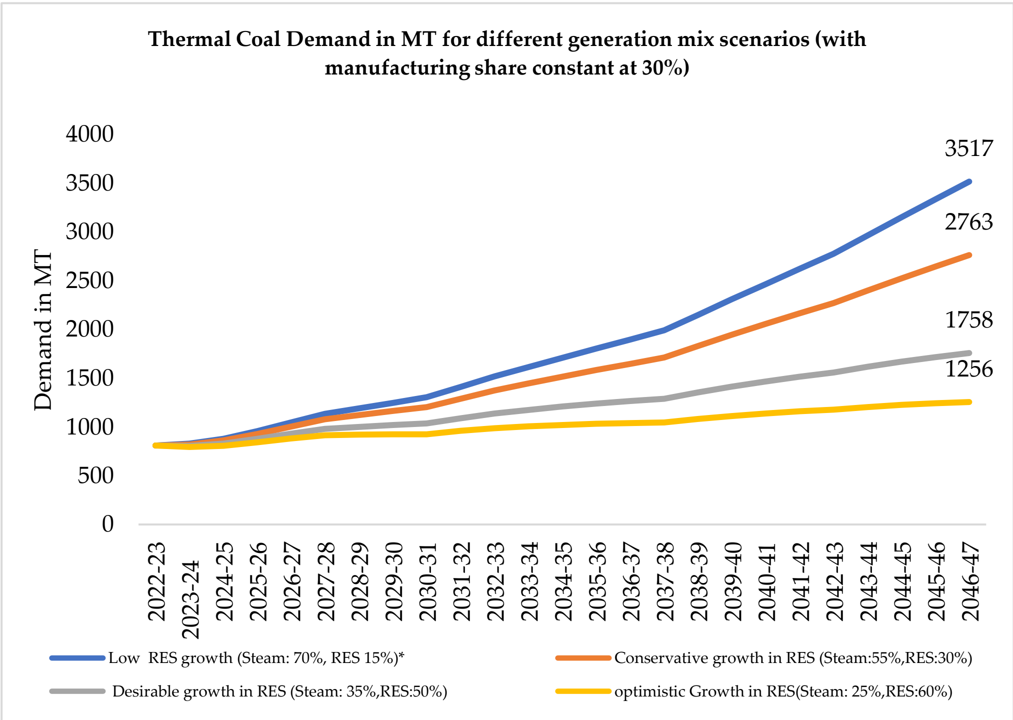


Figure 6 Demand for Coal when the share of manufacturing grows to 30% of GDP in 2047

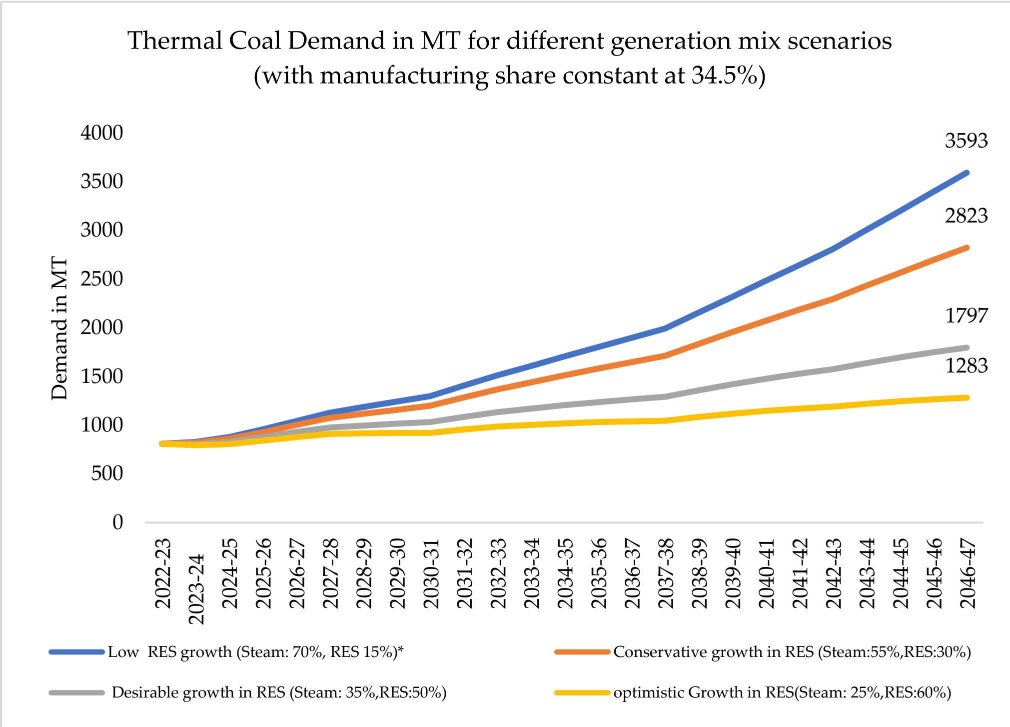


Figure 7 Demand for Coal when the share of manufacturing grows to 34.5% of GDP in 2047

5.2 Electricity Demand:

The projected electricity generation data for 2047 highlights a significant rise in total power demand across all scenarios, driven largely by economic growth and industrial expansion. As the share of manufacturing in GDP increases from 27% to 34.5%, total electricity generation rises from approximately 8,102 BU to over 8513 BU.

Table 8 Gross Electricity generation from all sources in 2047 across scenarios

Projected Demand of electricity generation in 2047 (in BU)	
Share of manufacturing in GVA in GDP	**Total**
Low (27%)	8102
Medium (30%)	8331
High (34.5%)	8513

This reflects the energy-intensive nature of manufacturing growth, which directly influences electricity demand. Steam-based generation—primarily from coal—varies widely depending on the generation mix. In the most ambitious High-RES scenario, where renewables contribute 60% of electricity generation and manufacturing is at 27%, steam-based generation still increases to around 2,037 BU—nearly double today's output. This indicates that while RES expansion may slow the relative dependence on coal, the absolute demand for electricity vis-a vis steam-based generation, will continue to rise substantially. These projections underscore the need for a realistic and well-coordinated energy transition strategy that considers both sectoral growth trajectories and supply-side planning.

Table 9 Electricity demand from steam-based power plants in 2047 under various scenarios

Projected Demand of electricity generation by steam in 2047 (in BU)				
	Variation in electricity generation mix#			
Share of Manufacturing GVA in GDP	Low growth in RES (Coal: 70%, RES 15%)	Conservative growth in RES (Coal:55%, RES:30%)	Desirable growth in RES (Coal: 35%, RES:50%)	Optimistic Growth in RES (Coal: 25%, RES:60%)
Low (27%)	**5671**	**4456**	**2836**	**2025**
Medium (30%)	**5832**	**4582**	**2916**	**2083**
High (34.5%)	**5959**	**4682**	**2980**	**2128**

#Varying share of Steam and RES. Balance 15% of generation is expected from Large Hydro/ Nuclear

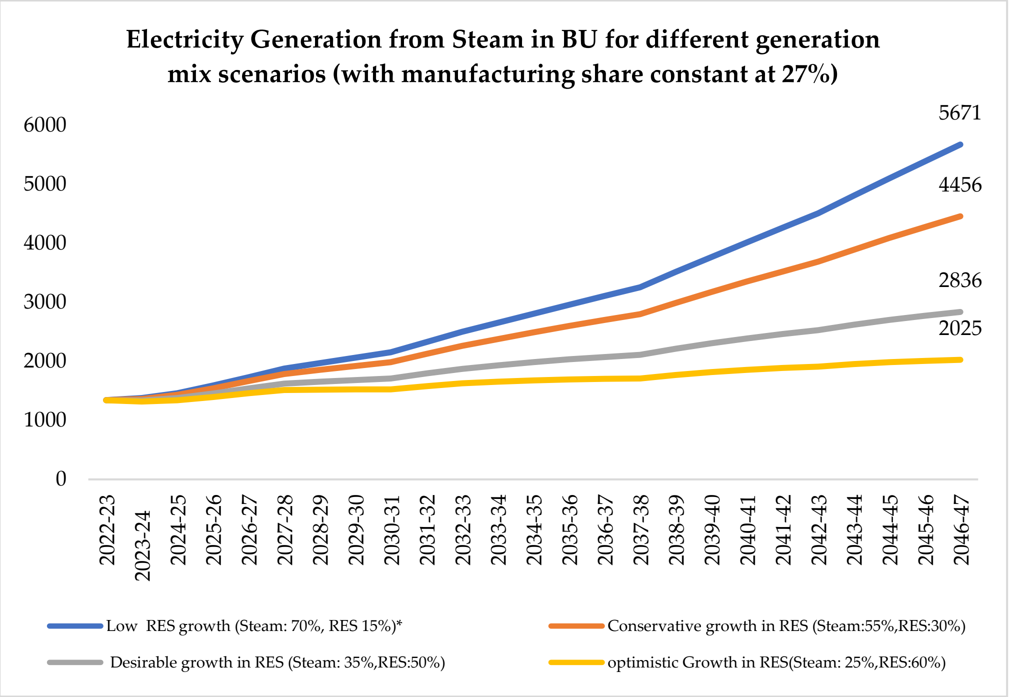


Figure 11 Steam based electricity generation when industry grows to 27% of GDP in 2047

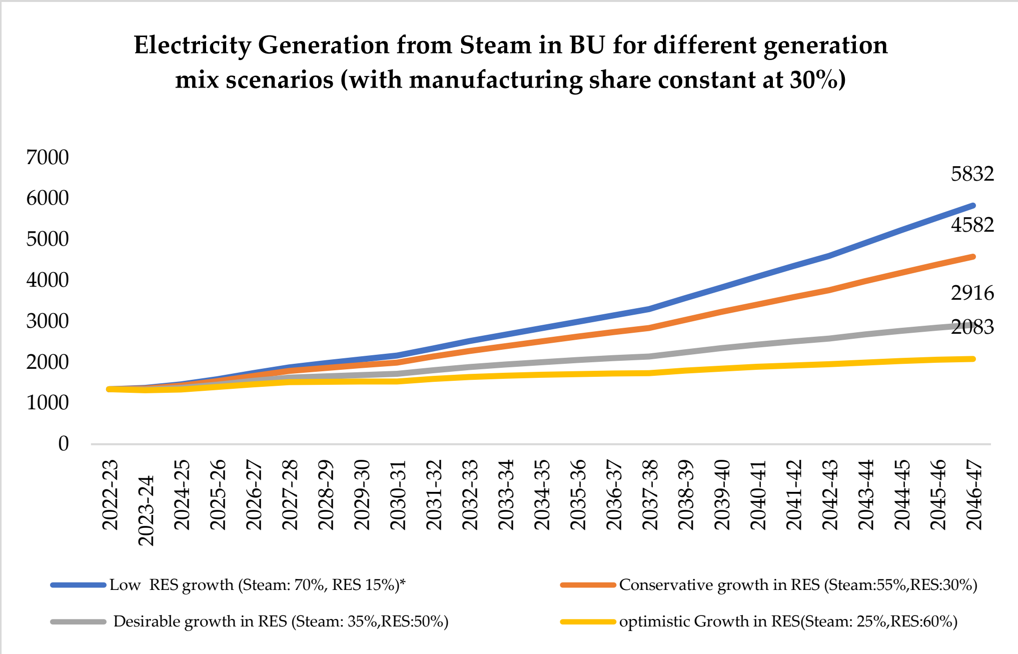


Figure 12 Steam based electricity generation when industry grows to 30% of GDP in 2047

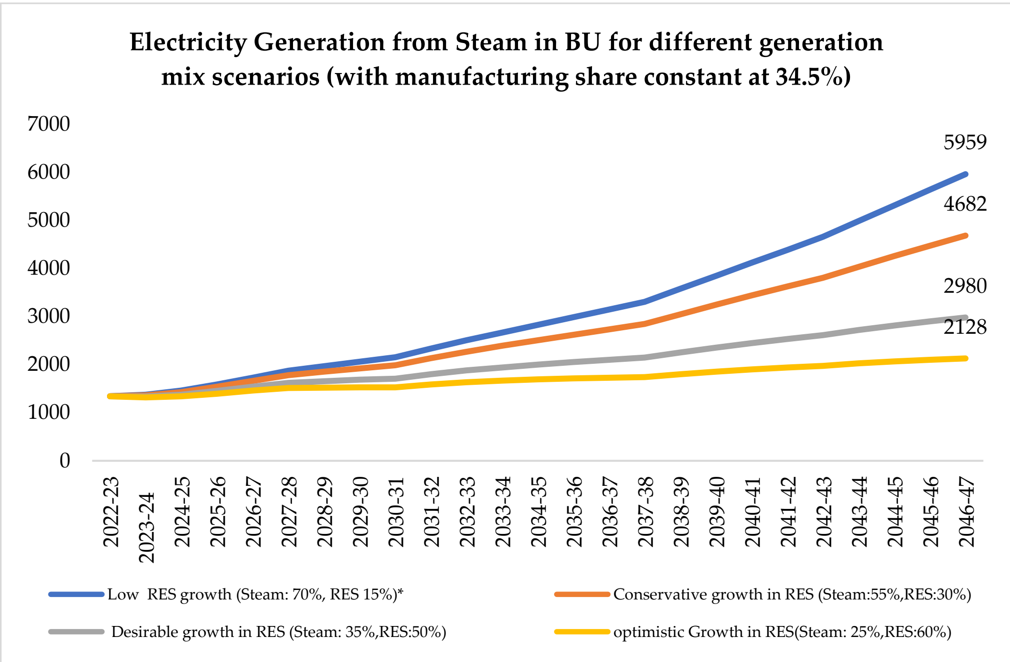


Figure 13 Steam based electricity generation when industry grows to 34.5% of GDP in 2047

5.3 Capacity requirement:

5.3.1 Coal fired plants:

The projections for coal-based thermal capacity in 2047 clearly reflect the interplay between industrial growth and the energy generation mix. As the share of manufacturing in GDP increases from 27% to 34.5%, the required thermal capacity correspondingly rises—from 1,077 GW to 1,132 GW under the low RES growth scenario, where coal remains dominant at 70% of electricity generation. In contrast, under the Optimistic RES Growth scenario with 60% RES generation, the thermal capacity requirement drops significantly to 385 GW for low manufacturing growth and 404 GW for high manufacturing growth. These results demonstrate that even in a future with aggressive RES deployment, substantial coal-based capacity will still be needed to ensure grid reliability and meet peak demand

Table 10 Steam capacity requirements in 2047 under various scenarios

	Projected requirement for coal-based thermal capacity in 2047 (in GW)			
	Variation in the electricity generation mix#			
Share of Manufacturing GVA in GDP	Low growth in RES (Coal: 70%, RES 15%)	Conservative growth in RES (Coal:55%, RES:30%)	Desirable growth in RES (Coal: 35%, RES:50%)	Optimistic Growth in RES (Coal: 25%, RES:60%)
Low (27%)	**1077**	**846**	**539**	**385**
Medium (30%)	**1107**	**870**	**554**	**396**
High (34.5%)	**1132**	**889**	**566**	**404**

 # Varying share of Steam and RES. Balance 15% of generation is expected from Large Hydro/ Nuclear

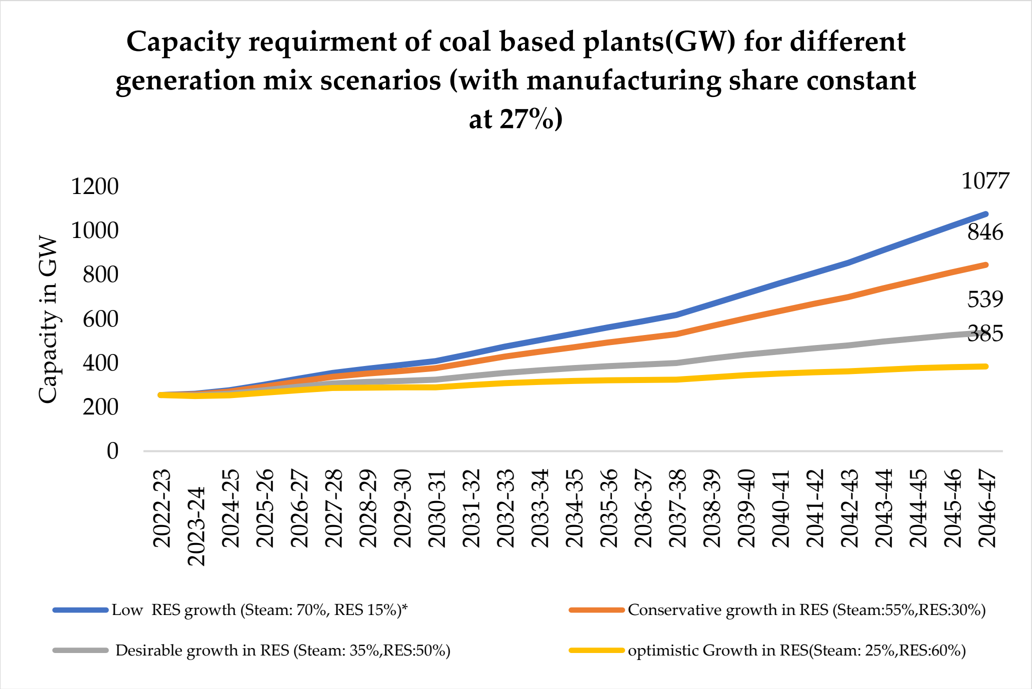


Figure 14 Steam Capacity requirements if industry grows to 27% of GDP in 2047

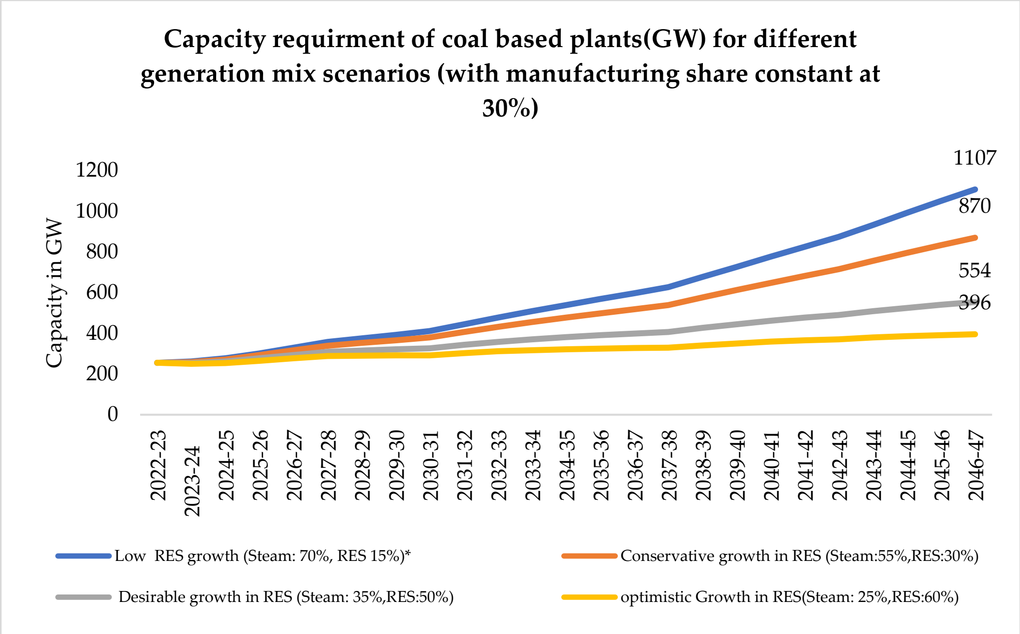


Figure 15 Steam Capacity requirements if the industry grows to 30% of GDP in 2047

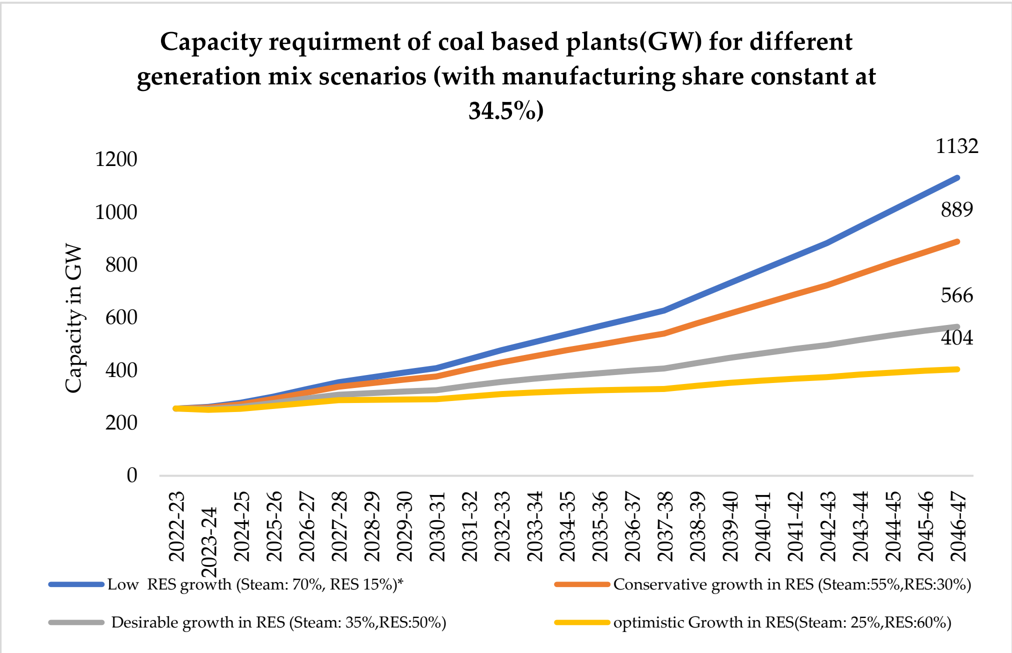


Figure 16 Steam Capacity requirements if industry grows to 34.5% of GDP in 2047

5.3.2 RES Capacity:

The projected capacity requirements for renewable energy (RES) in 2047 highlight the scale of infrastructure expansion needed under different energy transition pathways. As the share of RES in the electricity generation mix increases, the required RES capacity rises steeply across all levels of industrial growth. In the Low RES growth scenario, where RES contributes only 15% of generation, required capacity ranges from around 365 GW to 384 GW. However, under the Optimistic RES Growth scenario—where 60% of electricity is generated from renewables—the capacity requirement nearly quadruples, reaching between 1461 GW and 1535 GW. These figures underscore the massive scale of investment and infrastructure development needed to realize high renewable penetration, particularly in terms of land, storage, and grid integration. They also point to the urgency of parallel planning in transmission and storage capabilities to support such ambitious targets.

Table 11 RES capacity requirements in 2047 under various scenarios

	Projected capacity requirement for RES 2047(GW)			
	Variation in electricity generation mix			
Share of Manufacturing GVA in GDP	Low growth in RES (Coal: 70%, RES 15%)	Conservative growth in RES (Coal:55%, RES:30%)	Desirable growth in RES (Coal: 35%, RES:50%)	Optimistic Growth in RES (Coal: 25%, RES:60%)
Low (27%)	**365**	**730**	**1217**	**1461**
Medium (30%)	**376**	**751**	**1252**	**1502**
High (34.5%)	**384**	**767**	**1279**	**1535**

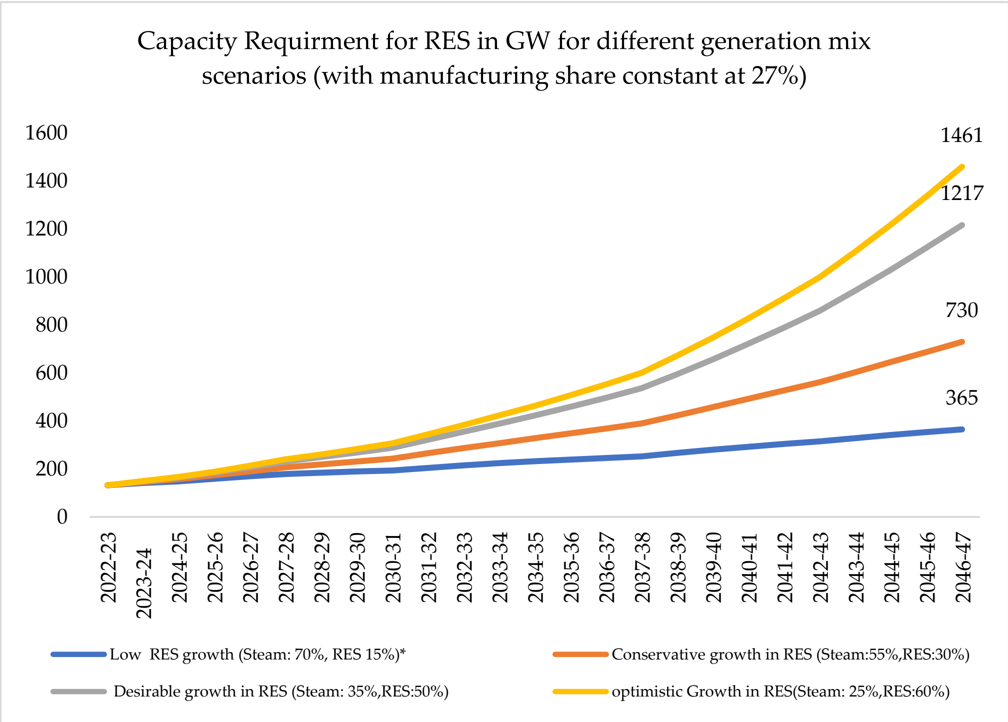


Figure 17 - 8 RES capacity requirement if industry grows to 27% of GDP in 2047

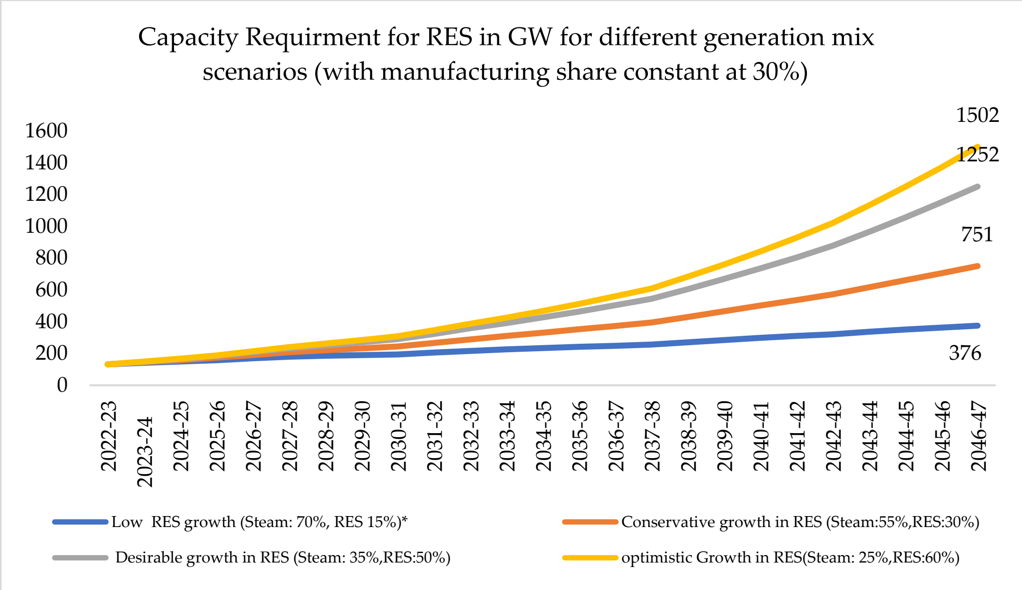


Figure 18 - 9 RES capacity requirement if industry grows to 30% of GDP in 2047

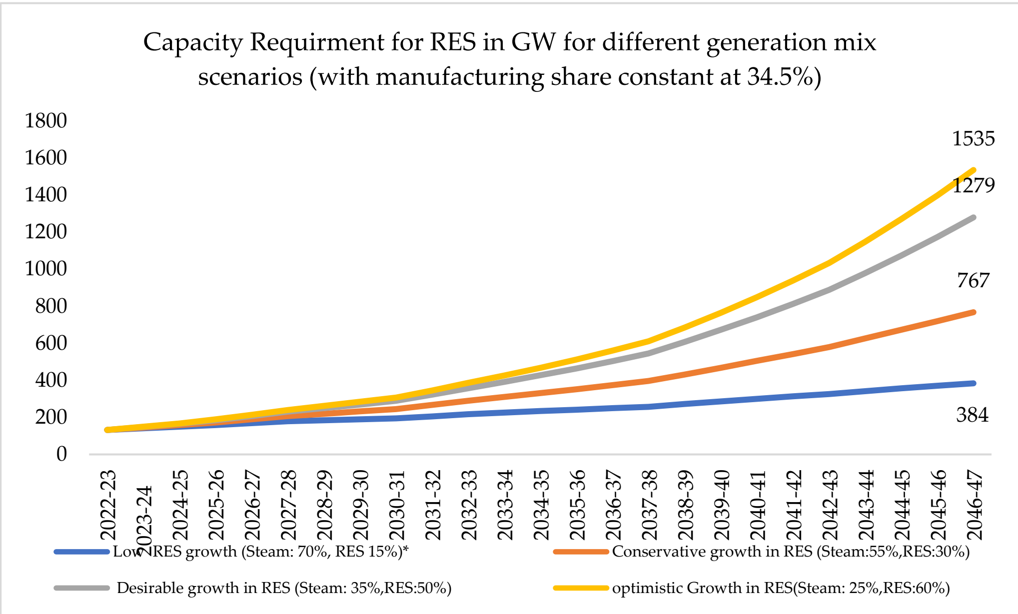


Figure 19 - 10 RES capacity requirement if industry grows to 34.5% of GDP in 2047

6. Socio-Economic Implication:

India's transition away from coal to renewable (as indicated by Fig 11 – 16, Table 6 – 7) is a complex and deeply consequential process. Coal is called the back gold of India (Singh, 2017) which has long served as the backbone of the nation's energy system, currently dominating electricity generation. However, its importance extends far beyond power production. The coal economy forms the foundation of a broader industrial ecosystem, supporting sectors such as mining, freight and logistics, thermal power generation, sponge iron, steel, and brick manufacturing (MoSPI, 2024).

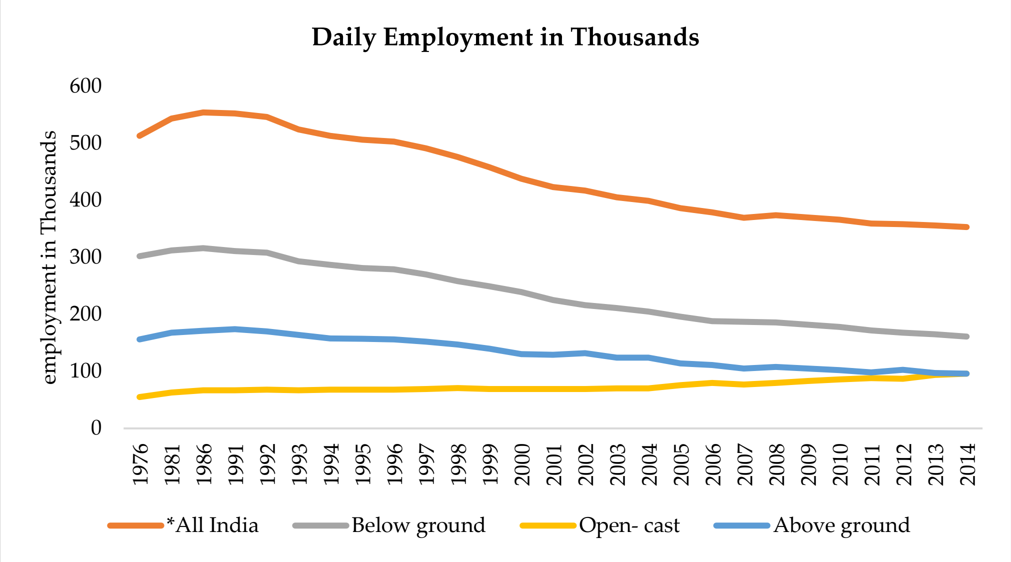


Figure 20 Source: Statistics Of Mines In India, Volume I (COAL) 2015 data set

Over the past few decades, employment in mines has declined due to increased mechanisation and automation. However, the mining sector still provides livelihoods to a significant number of people. At least 25% of the total workforce is directly employed in the mines.[7] It is estimated that over 13 million people are either directly or indirectly employed within this coal-based ecosystem (National Foundation of India, 2021). Any policy regarding coal phase-down will be associated with risks such as threats to energy security, creation of stranded assets, loss of livelihoods, technological complexities of transitioning to low-carbon technologies, increase in import dependency, and significant financial losses to the government's exchequer (Pandey, 2025). The coal-producing Public Sector Undertakings (PSUs) of the Government of India, notably Coal India Limited (including subsidiaries) and NLC India Limited, collectively employ a workforce of 369,053 individuals, including 128,236 contractual workers (PIB, 2024). The ongoing financial year has witnessed a further uptick in recruitment efforts, with Coal India Limited and its subsidiaries hiring 5,711 individuals under the Mission Mode Recruitment initiative. Concurrently, NLC India Limited has recruited 661 personnel during the same period, demonstrating a proactive approach towards addressing employment needs (PIB, 2024). Employment is through formal and informal employment in mines and power plants, and in coal transportation, processing, and allied services in a few coal-rich states such as Jharkhand, Chhattisgarh, West Bengal, Odisha, and Maharashtra (MoC, 2023-24). A study by the National Foundation for India highlights that 266 districts have at least one coal-linked asset such as a coal mine, thermal power plant, steel unit, or sponge iron facility. Alarmingly, 135 of these districts have two or more such assets, making their economies structurally tied to coal as the sector also generates royalties, land revenues, taxes for the fiscal health of these districts (National Foundation of India, 2021). For such regions, a transition away from coal is not merely an environmental policy shift—it represents a profound socio-economic transformation.

Initial estimates by ACPET, based on meta-analysis of thermal power plants and a social accounting matrix, indicate that under current economic conditions, phasing down coal and replacing it with renewable energy does not yield a significant net economic benefit. The model shows a marginal net loss of –0.01, suggesting that such a transition, in its present form, could lead to increased informalization, job losses, and broader welfare decline. This underscores the urgent need for targeted policy

[7] Coal Transition Odisha, a working paper (http://nfi.org.in/sites/nfi/files/publication/Coal%20Transition%20-%20Odisha-11-11-22%20%281%29.pdf)

intervention. Further evidence from ACPET's macroeconomic Social Accounting Matrix highlights how different sectors and household groups are adversely affected by the coal phase-down, reinforcing the need for a just and equitable energy transition. This aspect of the study has significant scope to be expanded and explored independently, using the SAM framework to examine distributional and sectoral impacts of the energy transition in greater depth in the future.
Without careful planning and support mechanisms, the transition from coal to renewables even in a 70% RES share could exacerbate existing inequalities and cause long-term economic distress in already fragile regions. Therefore, a people-oriented transition framework, which places people, especially workers and communities, at the centre of the shift, is essential. This involves not only retraining and reskilling workers but also creating new employment avenues, strengthening local governance institutions, diversifying regional economies, and ensuring social protection. Ultimately, the success of India's energy transition will depend on how inclusively and equitably it manages the decline of coal and whether it can turn this challenge into an opportunity for sustainable and just development.

7. Conclusions

India's per capita electricity consumption is way below the global average. As GDP and per capita income increase rapidly under Viksit Bharat trajectory, demand for electricity will rise to match needs of development and better living standards. This study attempts to empirically show that India's thermal coal demand is expected to rise in absolute terms until 2047, regardless of the electricity generation mix. Even in the most ambitious scenario—where 60% of electricity comes from renewables—coal demand increases by at least 55% over current levels, irrespective of the share of manufacturing in GDP. This however can phase down to 700 MMT in an aggressive 70% RES share scenario with 15% coal share and the rest 15% coming from others like nuclear and large hydro. In more realistic scenarios, where coal continues to account for around 60% of electricity generation, the coal demand is projected to more than double compared to current levels. This highlights a key insight: while renewable energy may decrease the rate of growth of coal demand, total coal consumption is still projected to rise, making it essential to plan for a gradual and managed transition.

The study therefore suggests that despite ambitious renewable energy (RE) targets and ongoing investments in solar, wind, and other clean technologies, coal is likely to remain a critical part of the energy mix at least until 2047.

This study raises an urgent and complex question—how should India approach mine closures and the coal phase-down? Transitioning to clean energy is essential to meet the 2070 net-zero goal, but premature or poorly planned mine closures could have damaging consequences. It risks destabilizing the socio-economic fabric of coal-dependent regions and jeopardizing national energy security. The coexistence of coal and renewables is therefore not a contradiction but a pragmatic approach to balancing growth with reliability for India's Viksit Bharat and Net Zero Goals by 2047 and 2070.

8. Reference:

1. Mohanty, A., & Chaturvedi, D. (2015). Relationship between electricity energy consumption and GDP: Evidence from India. International journal of economics and finance, 7(2), 186-202.

2. Asghar, Z. (2008). Energy-GDP relationship: a causal analysis for the five countries of South Asia. Applied Econometrics and International Development, 8(1).

3. Tongia, R., & Gross, S. (2019). Coal in India: Adjusting to transition.

4. Ferguson, R., Wilkinson, W., & Hill, R. (2000). Electricity use and economic development. Energy policy, 28(13), 923-934.

5. Ghosh, S. (2002). Electricity consumption and economic growth in India. Energy policy, 30(2), 125-129.

6. Warner, K. J., & Jones, G. A. (2019). The 21st century coal question: China, India, development, and climate change. Atmosphere, 10(8), 476.

7. Pandey, J. G., & Kumar, A. (2025). Navigating India's energy transition: A systematic literature review of risks in the coal phase-down process. Renewable and Sustainable Energy Reviews, 210, 115260.

8. Singh, K., Meena, R. S., Kumar, S., Dhyani, S., Sheoran, S., Singh, H. M., ... & Byun, C. (2023). India's renewable energy research and policies to phase down coal: Success after Paris agreement and possibilities post-Glasgow Climate Pact. Biomass and Bioenergy, 177, 106944.

9. Coal Controller's Organization. (2024). Coal Directory of India 2023–24. Ministry of Coal, Government of India. https://coal.gov.in/en/major-statistics/coal-statistics

10. World Bank (2022). Toward a just transition: A diagnostic on coal sector transition—Eastern India. World Bank. https://documents1.worldbank.org/curated/en/099513209032434771/pdf/IDU-13d06cd8-0fec-465e-a7e3-8a711ea131b8.pdf

11. Central Electricity Authority. (2024). All India electricity statistics: General review 2024. Ministry of Power, Government of India. https://cea.nic.in/all-india-electricity-statistics-general-review/?lang=en

12. India Brand Equity Foundation. (n.d.). Power sector in India. https://www.ibef.org/industry/power-sector-india#:~:text=This%20diverse%20mix%20highlights%20India's,the%20transition%20to%20clean%20energy

13. International Energy Agency. (2025). Global energy review: India energy statistics. https://www.iea.org/reports/global-energy-review-2025

14. Ministry of Coal. (2023–2024). Energy Cell annual report. Government of India.

15. Ministry of Coal. (2023–2024). Coal directory of India. Government of India

16. Mohapatra, S., & Sinha, A. (2024). Charting the path to a developed India: Viksit Bharat 2047. National Council of Applied Economic Research.

17. Ministry of Statistics and Programme Implementation. (2024). Energy statistics. Government of India.

18. National Foundation of India. (2021). Socio-economic impacts of coal transition in India. National Foundation of India.

19. Press Information Bureau. (2024, October 14). PM addresses ‘Global Maritime India Summit 2023’. https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2064702

20. Press Information Bureau. (2024, March 11). Union Cabinet approves policy to encourage clean energy. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2118788

21. Press Information Bureau. (2025). India becoming an economic powerhouse. https://www.pib.gov.in

22. Press Information Bureau. (2025, October 14). PM inaugurates new clean energy initiatives. https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154660

23. NITI Aayog. (2024). Vision for Viksit Bharat@2047: An approach paper. Government of India.

24. Warner, K. J., & Afanasyeva, S. (2017). A population-induced renewable energy timeline in nine world regions. Energy Policy, 101, 624–636. https://doi.org/10.1016/j.enpol.2016.11.030

25. Singh, S. U. (2017). Impacts of coal mining: A review of methods and practices. Current World Environment, 12(1), 142–150. https://doi.org/10.12944/CWE.12.1.17

26. Wooldridge, J. M. (2010). Econometric analysis of cross section and panel data. MIT press.

27. Jebaraj, S., & Iniyan, S. (2006). A review of energy models. Renewable and sustainable energy reviews, 10(4), 281-311.

28. Bhattacharyya, S. C., & Timilsina, G. R. (2010). Modelling energy demand of developing countries: Are the specific features adequately captured? Energy policy, 38(4), 1979-1990.