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CENTRE FOR A **People-centric Energy Transition**

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INDIA'S VIKSIT BHARAT @2047 AND NET ZERO @2070 GOALS: IMPACT ON COAL ECONOMY

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About Ashoka Centre for a People-centric Energy Transition (ACPET)

The Ashoka Centre for a People-centric Energy Transition (ACPET) is a research-focused, transdisciplinary Centre within Ashoka University, India, established to drive a sustainable, equitable, and "people-centric" shift towards net-zero emissions. It bridges the knowledge gap in energy transition by collaborating with industry and government to develop scalable solutions across renewable energy, policy, and technology. For further information about ACPET, please visit: acpet.ashoka.edu.in

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We also acknowledge the contributions of colleagues at ACPET who provided comments and feedback during the modelling and drafting stages.

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List of Abbreviations

SDG: Sustainable Development Goals

RES: Renewable Energy Sources (includes Solar, Wind, Small Hydro/Hydel, and Biomass)

ACPET: Ashoka Centre for a People-Centric Energy Transition

NITI: National Institution for Transforming India

CEA: Central Electricity Authority

GVA: Gross Value Added

GDP: Gross Domestic Product

CAGR: Compound Annual Growth Rate

IESS: India Energy Security Scenarios

NCAER: National Council of Applied Economic Research

T&D: Transmission and Distribution

kWh: Kilowatt-hour

GWh: Gigawatt-hour

TWh: Terawatt-hour

kg: Kilogram

CUF: Capacity Utilisation Factor

GW: Gigawatt

TW: Terawatt

BU: Billion Units

TU: Trillion Units

MT: Million Tonnes

BT: Billion Tonnes

EV: Electric Vehicle

AI: Artificial Intelligence

UWSSA: Unorganised Workers' Social Security Act

GoI: Government of India

NCEUS: National Commission for Enterprises in the Unorganised Sector

MoL&E: Ministry of Labour and Employment

PV: Photovoltaic

Li-ion: Lithium-ion

R&D: Research and Development

USC: Ultra-Supercritical

A-USC: Advanced Ultra-Supercritical

TPP: Thermal Power Plant

CCS: Carbon Capture and Storage

Source: ACPET

The Coal Economy in India’s Energy Transition

Need For a Macro and Socio-Economic Study on Coal in India

India is simultaneously striving to achieve two ambitious goals: becoming Viksit Bharat by 2047 and reaching Net Zero emissions by 2070. An expected outcome of this transition is the gradual phasing down of coal in the economy. Importantly, the vision of Viksit Bharat is inherently inclusive and multi-sectoral, aligned with a wide range of Sustainable Development Goals (SDGs) spanning economic growth, social development, and environmental sustainability. Energy access plays a central role in this transformation, influencing mobility, health, education, and income generation that underpin India’s development trajectory. Energy and economic development have historically been closely linked (Stern, 2011). As India aspires to become a high-income country by 2047 (World Bank, 2024), this growth trajectory will inevitably translate into rising energy demand.

At the same time, achieving net-zero emissions by 2070 forms a key component of India’s long-term development strategy. It reduces exposure to climate-related risks, avoids carbon lock-in in infrastructure, strengthens long-term energy security, and enhances competitiveness in a carbon-constrained global economy. The pathway toward net zero implies gradual decarbonisation of the energy system through improvements in energy efficiency, large-scale deployment of renewable energy sources (RES), and a steady reduction in high-emission fuels. Within this transition, coal presents a particularly complex challenge. It remains central not only to the electricity system but also to regional economies, public revenues, and industrial supply chains.

Global literature often examines coal reduction in mature economies with declining demand. Fast-growing, electricity-intensive economies face different dynamics. Understanding these dynamics in the Indian context is therefore essential for informed policy planning. Its importance has increased further amid growing geopolitical tensions surrounding regions rich in oil and gas reserves. As these tensions intensify, countries may increasingly prioritise domestic energy resources to reduce exposure to volatile global energy markets. In such circumstances, future investments in coal assets may reinforce coal dependence in the long run.

Even before the impact of coal phase-down is considered, a fundamental question arises: whether India, as a strong voice of the Global South and a rapidly growing economy with growth expectations of around 8 per cent, can realistically accommodate or even consider phasing out coal in the short, medium, and long term. Electricity demand is expected to grow significantly as India advances toward the Viksit Bharat vision. Rapid industrial expansion, urbanisation, rising incomes, and structural shifts such as automation, electric mobility, data centres, and digital infrastructure are expected to drive substantial increases in electricity consumption in the coming decades.

In the presence of intermittency in renewable energy sources such as solar and wind, and in the absence of adequate storage capacity, coal-based electricity generation is likely to remain an important component of India's power system in the short and medium term. While India's net-zero pathway implies a gradual moderation of coal dependence over the long term, current policy discourse emphasises stabilising coal within a broader energy transition framework. This raises a central policy question: how will coal demand evolve as India simultaneously pursues rapid economic growth and long-term decarbonisation?

Coal has historically played a central role in India's economic development. The coal economy encompasses mining communities, transport networks, machinery and equipment manufacturers, thermal power plants, and numerous ancillary industries. Coal also supports broader economic systems. Revenues from coal transportation account for nearly half of Indian Railways' freight earnings, while several eastern states derive significant royalty and cess revenues from coal production.

Despite its high carbon intensity, coal remains deeply embedded in India's growth model and energy architecture. Its domestic availability makes it a critical source of reliable and affordable electricity for industry, households, and services. At the same time, India's commitment to net-zero emissions implies that coal-dependent sectors will gradually undergo structural transformation. This transition raises concerns for nearly 13 million workers directly and indirectly employed in the coal economy (National Foundation for India, 2024), spanning mining, transportation, power generation, and associated industries. The transition away from coal is therefore not only an economic or climate question. It also involves issues of distributive justice, procedural justice, and recognition of communities whose livelihoods are tied to coal.

A people-centric transition requires recognising the social and regional dimensions of the coal economy. Coal-producing regions face complex challenges associated with employment transitions, community identities, and long-standing structural dependencies on coal-based industries. From this perspective, the coal phase-down must be understood not merely as a technological shift in the energy system, but as a broader socio-economic transformation. Ensuring a just transition, therefore, requires strengthening social protection systems, expanding opportunities for skill development, supporting economic diversification in coal-dependent regions, and enabling meaningful participation of affected communities in transition planning. Against this backdrop, the present analysis examines the future trajectory of the coal economy by estimating India's electricity demand, electricity generation mix, and thermal coal requirements under alternative growth and electricity generation mix scenarios.

The study was initiated in mid-2025 as a forward-looking strategic planning exercise at a time when comprehensive long-term assessments of coal demand trajectories, capacity expansion requirements, and realistic transition timelines in the India-specific context were limited. The analysis suggests that while the share of coal in electricity generation will decline over time, the absolute volume of coal used for power generation may continue to increase at least until 2050 due to rising electricity demand. At the same time, global geopolitical developments may influence these trajectories. Political tensions in major energy-producing regions and volatility in international gas markets could reinforce the role of coal as a domestic energy security buffer in the near to medium term.

India's Electricity and Coal Conundrum

India's Energy Structure and Coal

India's primary energy sources include coal, oil, natural gas, and non-fossil sources such as large hydro and nuclear, along with RES - solar, wind, biomass, and small hydro. Among these, coal continues to dominate India's energy mix, accounting for more than 50 per cent of primary energy supply (Ministry of Statistics and Programme Implementation, 2025).

Electricity is the most significant secondary form of energy used across sectors such as industry, transport, agriculture, commercial establishments, and households. The trajectory of future coal demand is therefore closely intertwined with the evolution of electricity demand. At present, around 70 per cent of raw coal consumption in India is directed toward the power sector, making electricity generation the single largest driver of coal use.

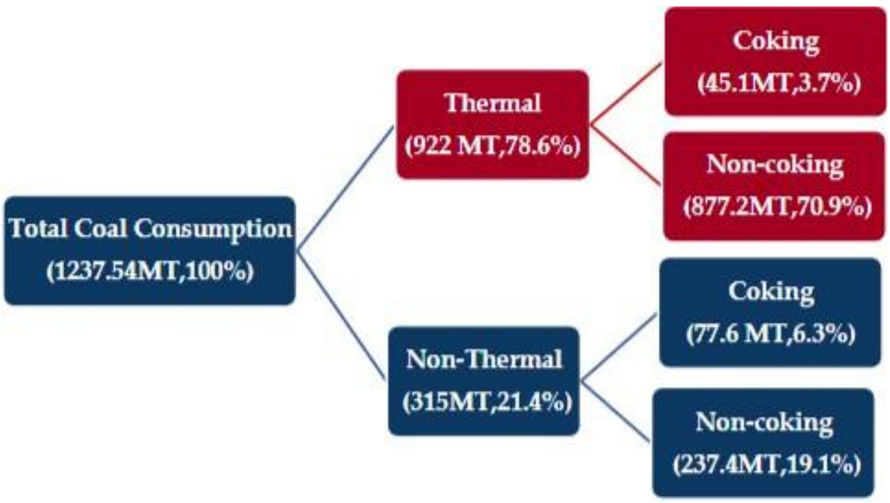

Figure 1: Categorisation of Coal in India Source: Coal

Directory 2023-24 (Ministry of Coal)

Rising Electricity Demand in a Growing Economy and the Future of Coal

India's development aspirations under the Viksit Bharat @2047 vision are expected to significantly increase electricity demand. Expansion in manufacturing activity, rising urbanisation, digitalisation of economic transactions, increasing per capita incomes, and large-scale infrastructure development in transport and logistics are likely to contribute to sustained growth in electricity consumption.

India's per capita electricity consumption also remains substantially below the global average. For instance, China, a country comparable in size and population, consumes nearly five times more electricity per capita. As India moves toward high-income status by 2047, electricity demand is expected to rise considerably, reflecting both economic expansion and convergence toward higher energy consumption levels.

Higher electricity demand would normally translate into higher coal demand. However, the pace of coal use will increasingly depend on the expansion of non-fossil electricity sources in line with India's commitment to net-zero emissions by 2070.The present structure of electricity generation in India reflects the dominant role of thermal power, particularly coal-based generation.

Table 1: Generation Mix

Share of Sources in Electricity Generation				
Year		Steam	RES	Others
2022-23	Reported in 2024	74%	12%	14%

Steam includes coal-fired plants; RES includes Solar, Wind, Small Hydro and Biomass; Others include Nuclear, Large Hydro, Diesel and Gas; Source: CEA General Review 2024

India has already embarked on expanding non-fossil electricity generation capacity, particularly in solar and wind energy. As RES capacity increases, the share of coal in the electricity generation mix is expected to gradually decline. Given these strong linkages, a scenario-based analysis has been undertaken by ACPET focusing on coal consumption in the power sector and future electricity demand under alternative economic growth pathways. The analysis assesses the impact of differing electricity generation mix assumptions on estimated thermal coal demand.

While coal is also used in sectors such as iron, steel, cement, and aluminium, these non-power uses are driven by distinct structural, technological, and policy factors and are therefore outside the scope of this analysis. As the power sector remains by far the largest consumer of coal in India, understanding how coal demand evolves in electricity generation is critical to assessing the future trajectory of coal use and its implications for India's energy transition.

Importantly, changes in coal use within electricity generation have implications far beyond the energy system. They influence employment in mining and logistics, rail freight revenues, fiscal resources of coal-producing states, and the affordability and reliability of electricity supply.

Against this backdrop, the analysis seeks to address the following questions:

a) How will India's electricity demand evolve under different economic growth scenarios up to 2047 and 2070?
b) What thermal coal demand trajectories emerge from these electricity demand pathways?
c) What scale of non-coal electricity capacity expansion would be required to reduce dependence on coal-based generation?
d) What policy approaches are required to ensure that India's electricity transition remains orderly, inclusive, and aligned with both development and climate goals?

To address these questions, a macroeconomic modelling framework has been developed linking economic growth, electricity demand, generation mix, and thermal coal demand across the two key time horizons of 2047 (Viksit Bharat) and 2070 (Net Zero).

Analytical Framework

The analytical framework used in this study adopts a sector-driven, sequential approach that links multi-sectoral economic growth to electricity demand, electricity generation, fuel requirements (coal and non-coal), and the associated infrastructure required to support electricity supply. The modelling is undertaken under multiple scenarios of economic growth and electricity generation mix up to 2047, aligned with India's vision of Viksit Bharat, and further extended to 2070, aligned with India's Net Zero commitment.

The framework is designed to be transparent, scenario-based, and suitable for long-term policy analysis, while remaining grounded in historical data trends and empirically estimated relationships.

Overview of the Modelling Framework

The modelling framework follows a sequential structure linking economic growth to electricity demand and electricity supply outcomes:

Economic growth → Sectoral electricity demand → Gross electricity generation → Source-wise electricity generation → Thermal coal demand → Installed capacity requirements

This stepwise structure ensures that assumptions related to economic growth, efficiency improvements, and electricity generation mix are consistently reflected across electricity demand projections, fuel requirements, and capacity planning outcomes.

The base year for the analysis is 2022–23, aligned with the latest officially available data on sectoral economic output, electricity sales, and electricity generation mix. The data has been validated using official sources, including the Central Electricity Authority (CEA) and NITI Aayog.

The process workflow of the model is as follows (Fig. 2) -

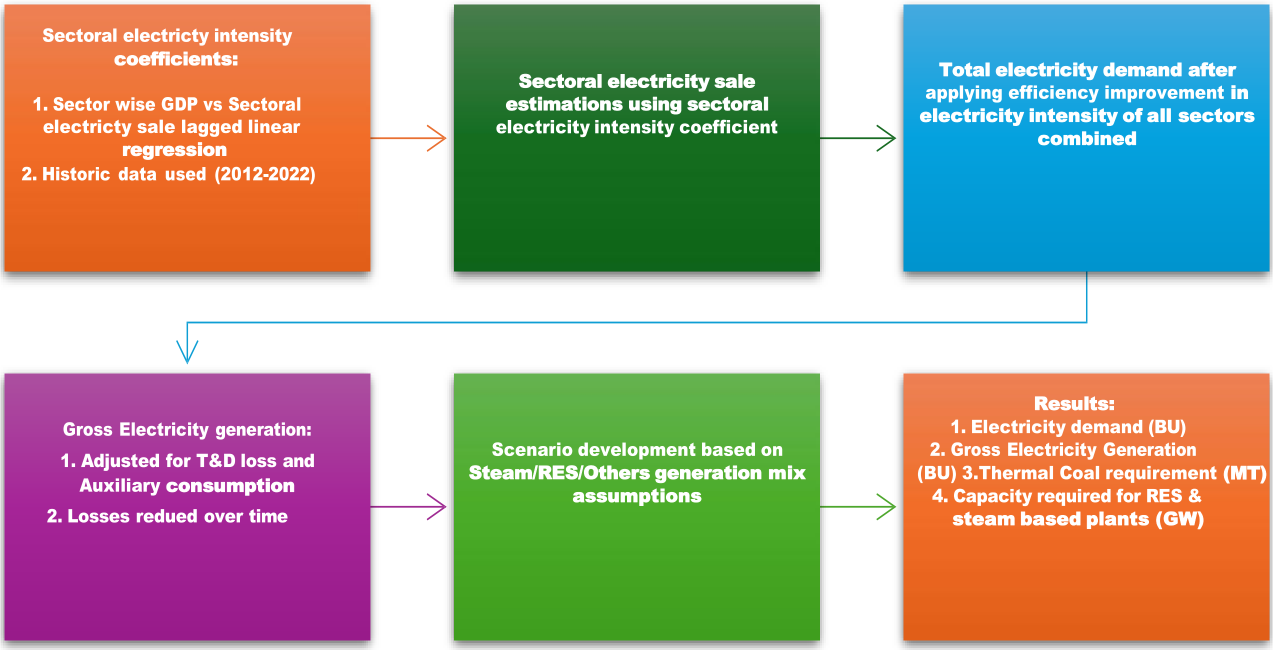

Figure 2: Model Framework

Economic Growth and Sectoral Structure

The Indian economy is represented using three broad sectors:

a) Agriculture
b) Industry
c) Services

Future electricity demand is driven by projections of sectoral economic activity, represented by sectoral Gross Value Added (GVA) or Gross Domestic Product (GDP). These projections are derived from assumptions regarding overall GDP growth and the evolving sectoral composition of the economy as India progresses toward the Viksit Bharat 2047 vision.

GDP Growth Assumptions

Two phases of economic growth are assumed:

Up to 2047: GDP grows at a compound annual growth rate (CAGR) of 7 per cent, consistent with the medium-growth trajectory outlined in NITI Aayog's India Energy Security Scenarios (IESS) V3.

From 2047 to 2070: Economic growth moderates to approximately 5 per cent annually, reflecting a gradual transition toward a mature high-income economy. This assumption is consistent with long-term projections from institutions such as NITI Aayog and NCAER.

These assumptions reflect sustained high growth during India's development phase, followed by moderated growth as the economy matures.

Sectoral Composition Scenarios

Alternative assumptions regarding sectoral shares in GDP are used to capture potential structural transformation in the economy, particularly the possibility of manufacturing-led growth (refer to Table 2).

Table 2: Scenarios for Sectoral Share in GDP by 2047

Scenario	Agriculture	Industry	Services
Base year (2022)	15.3%	21.4%	63.3%
Low industry growth	10.0%	27.0%	63.0%
Medium industry growth	10.0%	30.0%	60.0%
High industry growth	6.8%	34.5%	58.7%

The high-industry-share pathway is adopted from NITI Aayog's IESS V3, reflecting policy emphasis on manufacturing-led economic growth.
The analysis indicates that thermal coal demand is not significantly different under scenarios of variation in the industry sector's share of GDP. In contrast, thermal coal demand varies significantly in response to changes in the electricity generation mix.

Accordingly, for projections towards 2070, a steady 30 per cent industry share in GDP has been adopted (refer to Table 3).

Table 3: Sectoral Share in GDP: 2070

Year	Agriculture	Industry	Services
2022	15%	21%	63%
2047	10%	30%	60%
2070	10%	30%	60%

Estimating Sectoral Electricity Demand

Sectoral electricity demand is estimated by linking electricity sales to sectoral economic activity using historical data for the period 2012–2022[1].

Historical data used for the estimation includes:

a) Sectoral GVA/GDP (Reserve Bank of India)[2]
b) Sector-wise electricity sales (Central Electricity Authority)

Sectoral electricity demand projections are derived using empirically estimated relationships between sectoral economic output and electricity consumption. A one-year lag structure is incorporated to reflect the adjustment between economic activity and electricity demand and to reduce concerns of reverse causality (Wooldridge, 2010).

The estimated coefficients used for projections are presented below.

Table 4: Regression Coefficients and Intercepts

Sector	Coefficient	Intercept
Agriculture	0.12	21633.9
Industry	0.16	70726.9
Services	0.06	19267.2

The relative magnitudes of these coefficients reflect sectoral characteristics:

a) Industry exhibits the highest electricity responsiveness due to electricity-intensive manufacturing and industrial processes.

b) Agriculture shows moderate responsiveness, reflecting increasing mechanisation and electrification.

[1] A 10-year historical window was used for regression estimation to ensure statistical robustness while capturing recent structural shifts in India's economy.

[2] Sectoral Gross Value Added (GVA) or sectoral GDP is aggregated into three broad sectors: Agriculture (Agriculture, Forestry and Fishing); Industry (Mining and Quarrying, Manufacturing, and Electricity, Gas, Water Supply and Other Utility Services); and Services (Construction; Trade, Repair, Hotels and Restaurants; Transport, Storage, Communication and Services Related to Broadcasting; and Financial, Real Estate and Professional Services). Public Administration, Defence and Other Services come under a separate bracket, which is not considered in this study.

c) Services exhibit lower electricity intensity on average.

Projected electricity demand is subsequently adjusted to account for improvements in electricity efficiency across sectors.

Adjusting Electricity Demand for Efficiency Improvements

Projected electricity demand is adjusted to reflect expected improvements in electricity efficiency due to technological progress, improved efficiency standards, and structural changes in the economy.

The following assumptions are applied:

a) By 2047: a uniform 5% reduction in electricity demand (derived conservatively from historical trends)[3].
b) By 2070: two alternative efficiency scenarios of 10% and 15% reduction in electricity demand.

The efficiency adjustment is applied uniformly across sectors due to uncertainty around sector-specific technological change trajectories.

Estimating Gross Electricity Generation

Electricity demand estimated through sectoral projections represents final electricity sales. To estimate the electricity generation required to meet this demand, system-level losses and auxiliary consumption are incorporated.

Gross electricity generation, therefore, includes:

a) Transmission and distribution (T&D) losses
b) Auxiliary consumption within power plants

Table 5: Assumptions on Auxiliary Consumption and T&D losses

Year	Auxiliary Consumption	T&D Loss
2022	5.80%	15.80%
2047	5.00%	10.00%
2070	4.50%	6.00%

These values reflect assumed improvements in system performance over time.

Source-wise Electricity Generation Scenarios

Gross electricity generation is allocated across three broad sources:

a) Steam (coal-based)
b) Renewable Energy Sources (RES) - solar, wind, biomass, small hydro

[3] Author's calculation based on data from Ministry of Statistics and Programme Implementation, Energy Statistics India 2025 (2025).

c) Others - nuclear, large hydro, gas, diesel

Multiple electricity generation mix scenarios are imposed to estimate the likely range of thermal coal demand and the associated capacity requirements.

Table 6: Scenarios for Electricity Generation Mix: By 2047

Scenario	Steam	RES	Others
Low-RES growth	70%	15%	15%
Conservative RES growth	65%	20%	15%
Desirable RES growth	35%	50%	15%
Optimistic RES growth	25%	60%	15%

The pace and scale of RES expansion have a substantial impact on demand for thermal coal and capacity required for thermal power and RES plants.

Among the scenarios assessed, the “desirable growth” pathway under which RES account for 50% of total electricity generation by 2047, produced results most closely aligned with projections by NITI Aayog and other comparable studies. Accordingly, this scenario has been adopted as the base case for the extended analysis from 2047 to 2070.

Table 7: Scenarios for Electricity Generation Mix: By 2070

Scenario	Steam	RES	Others
Scenario 1	25%	63%	12%
Scenario 2	15%	73%	12%
Scenario 3	11%	77%	12%

Disaggregation of RES Electricity Generation

Electricity generation from RES is further disaggregated into individual technologies broadly in line with observed shares (CEA, 2024).

a) Solar
b) Wind
c) Biomass
d) Small hydro

Solar is assumed to remain the dominant component of future RES expansion, consistent with recent deployment patterns and policy targets (Singh, 2023; Ministry of Power, 2024).

Table 8: Assumptions on the share of RES sources in RES-based electricity generation

Year	Solar	Wind	Biomass	Small Hydro
2023	51%	37%	8%	4%
2047	60%	30%	5%	5%
2070	68%	25%	4%	3%

Estimating Thermal Coal Demand

Thermal coal demand is derived directly from electricity generated from steam-based power plants. A constant coal consumption factor of 0.6035 kg of coal per kWh is applied to projected steam-based electricity generation. This factor is based on historical trends and is treated as stable over the past decade. The resulting coal demand estimates represent total thermal coal requirements (domestic and imported), expressed in million tonnes.

Installed Capacity Estimation

Installed capacity requirements are estimated separately for RES and steam-based (coal) power plants.

RES Capacity

For RES technologies, capacity-to-generation conversion is based on observed performance and assumed improvements in capacity utilisation factors (CUFs).

Table 9: Assumptions on CUFs of RES Sources

Year	Solar	Wind	Biomass	Small Hydro
2022	17%	19%	20%	26%
2047	40%	38%	28%	30%
2070	40%	38%	28%	30%

These CUFs are used to estimate technology-specific installed capacity from projected electricity generation, aggregated to total RES capacity.

Steam-based (Coal) Capacity

Steam-based installed capacity is estimated using a capacity-to-generation conversion factor derived from recent system performance:

0.1899 GW per billion units (BU) of electricity generation

This factor is assumed to remain constant over time, reflecting technological maturity and the continuing balancing role expected from coal-based capacity in a RES-heavy power system.

Scenario Design

The framework evaluates multiple scenarios to capture alternate trajectories of sectoral economic growth, electricity generation mix, and efficiency improvements.

2047	2070
a) 3 industrial growth pathways	a) 1 industrial growth pathway
b) 4 electricity generation mix scenarios	b) 3 electricity generation mix scenarios
c) 12 total scenarios	c) 2 electricity efficiency scenarios
	d) 6 total scenarios

Policy Relevance of the Framework

By explicitly linking economic growth, electricity demand, generation mix, thermal coal use, and installed capacity requirements, this analytical framework enables policymakers to:

a) assess trade-offs between coal-based generation and RES expansion, including the associated infrastructure implications
b) identify risks of misalignment between electricity demand growth and electricity system evolution

The framework provides a consistent and transparent basis for long-term planning toward India's development milestones of 2047 and 2070. It also helps identify the timing and scale of adjustments required in the electricity system to accommodate development-driven demand growth while gradually moderating coal dependence, enabling stakeholders to undertake timely and informed action.

Results

This study evaluates 12 scenarios for the period 2022–2047, along with six extended scenarios covering 2047–2070. For simplicity and clarity, results are presented for two analytical horizons aligned with India's key milestones: 2047 under the Viksit Bharat vision and 2070 under India's Net Zero commitment.

Electricity Demand

Electricity demand increases across all scenarios by 2047, driven by economic growth and industrial expansion. As industry's share in GDP rises from 27% to 34.5%, electricity demand increases from about 6,927 BU to over 7,279 BU. This reflects the higher electricity intensity of industrial activity and the strong link between economic growth and electricity consumption.

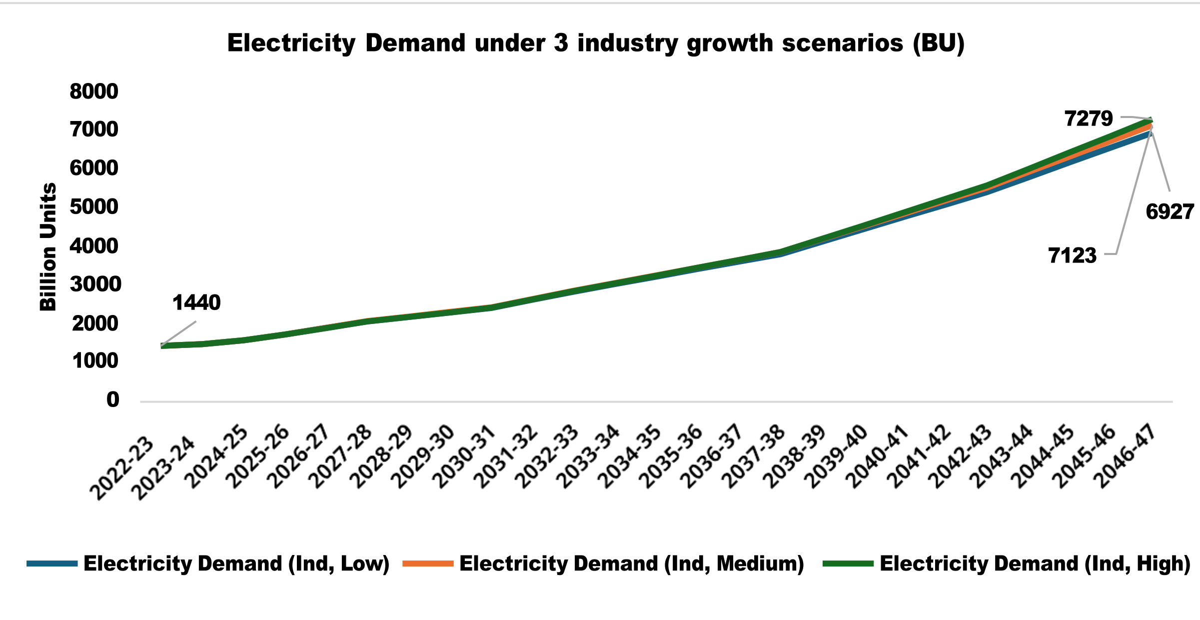

Figure 3: Electricity Demand by 2047 across scenarios Table 10:

Electricity Demand by 2047 across scenarios

Projected demand of electricity by 2047 (in BU)	
Share of industry in GDP	Total
Low (27%)	6927
Medium (30%)	7123
High (34.5%)	7279

Electricity demand continues to rise beyond 2047. By 2070, demand reaches 24,044 BU under the 10% efficiency scenario and 22,708 BU under the 15% efficiency scenario. Although efficiency improvements reduce demand by about 1,300 BU, consumption remains high due to economic growth, expanding electrification, growth in manufacturing and infrastructure, and rising living standards. Efficiency gains moderate electricity demand but does not alter the long-term upward trajectory.

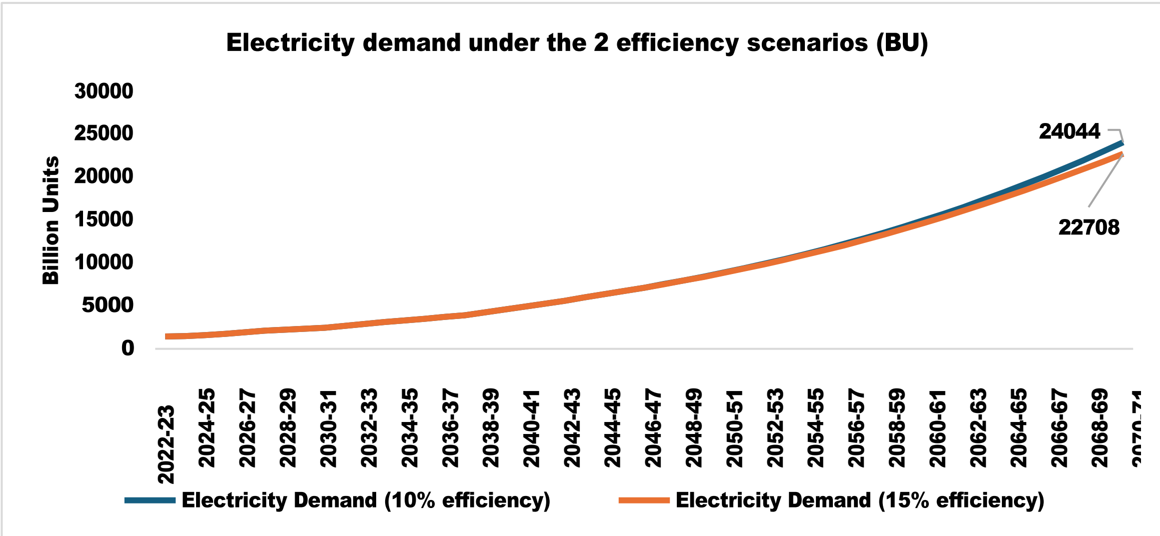

Figure 4: Electricity Demand by 2070 across scenarios Table 11:

Electricity Demand by 2070 across scenarios

Projected Demand of electricity by 2070 (in BU)	
10% efficiency	24044
15% efficiency	22708

Gross Electricity Generation

Gross electricity generation includes transmission and distribution losses and auxiliary consumption in power plants. As a result, generation requirements closely track electricity demand across all scenarios.

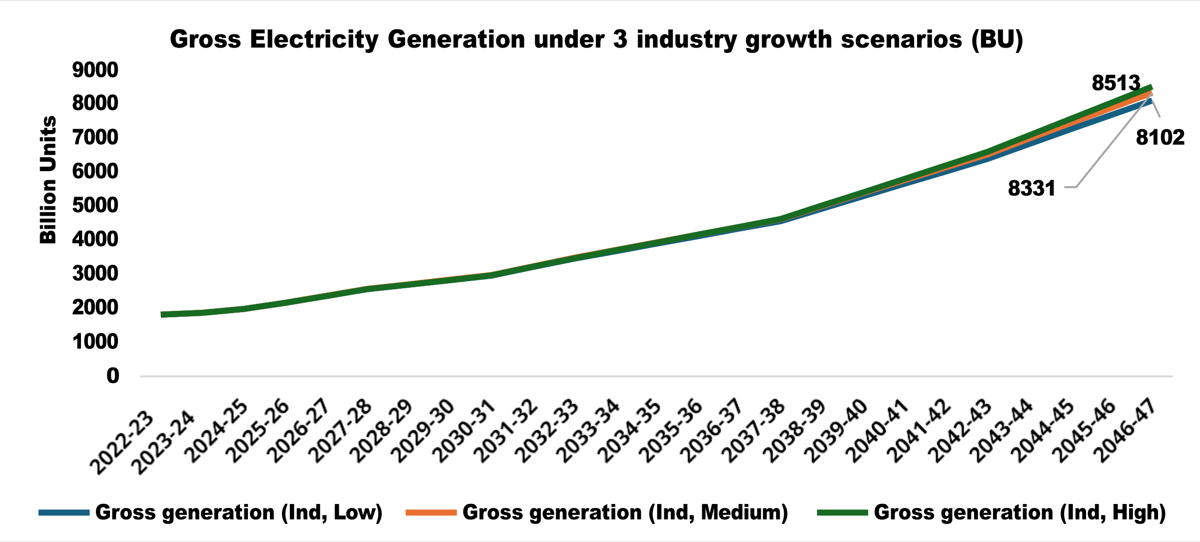

Figure 5: Gross Electricity Generation by 2047 across scenarios Table 12:

Gross Electricity Generation by 2047 across scenarios

Projected gross electricity generation by 2047 (in BU)	
Share of industry in GDP	Total
Low (27%)	8102
Medium (30%)	8331
High (34.5%)	8513

By 2070, gross generation reaches approximately 26,784 BU under the 10% efficiency scenario and 25,296 BU under the 15% efficiency scenario.

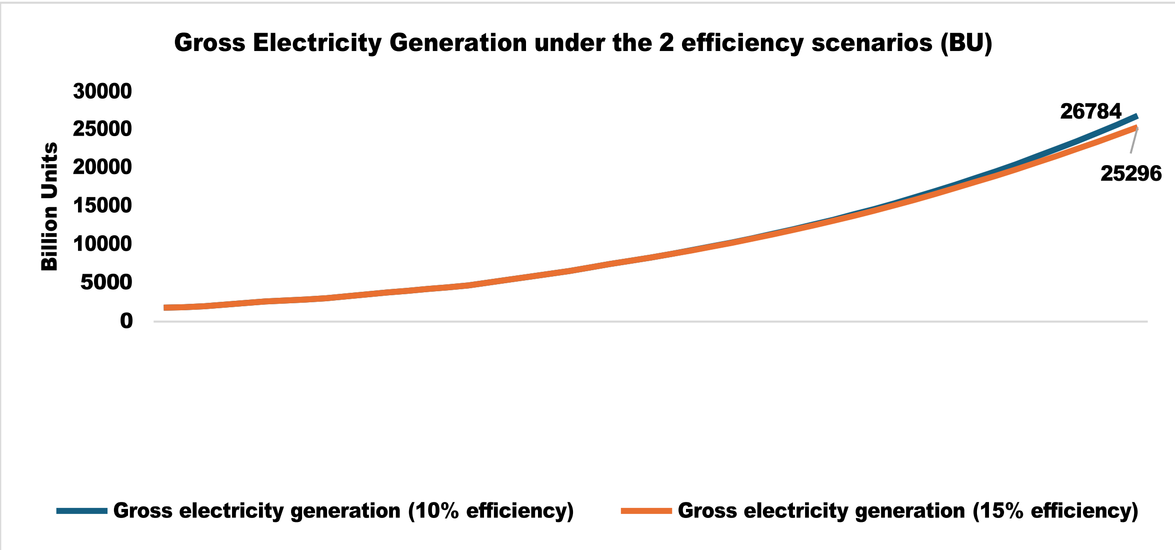

Figure 6: Gross electricity generation by 2070 across scenarios

Table 13 : Gross Electricity Generation by 2070 across scenarios

Projected gross electricity generation by 2070 (in BU)	
10% efficiency	26784
15% efficiency	25296

Generation from Steam

Steam-based generation, primarily coal-based, varies with the generation mix. In the most ambitious high-RES scenario, where RES contribute 60% of electricity generation, and industry's share is 27%, steam-based generation still rises to about 2,025 BU, nearly double today's output. This suggests that while RES expansion reduces the relative dependence on coal, absolute demand for electricity and steam-based generation continues to increase. These projections highlight the need for a realistic and coordinated energy transition strategy that accounts for both sectoral growth and supply-side planning.

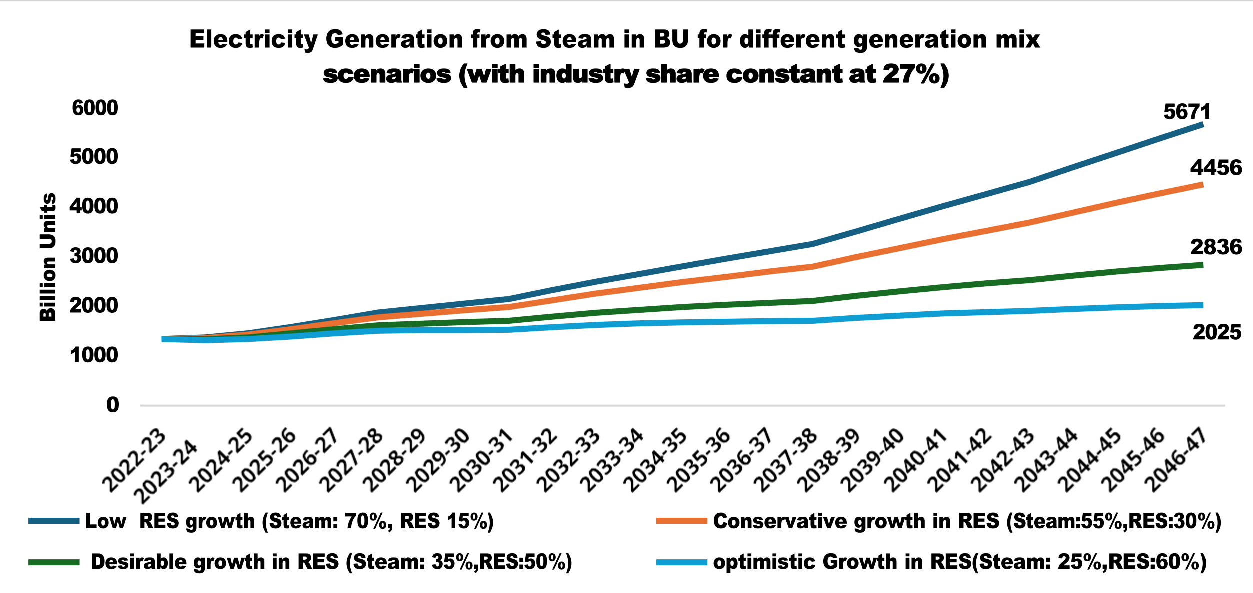

Figure 7: Electricity Generation from Steam when industry grows to 27% by 2047

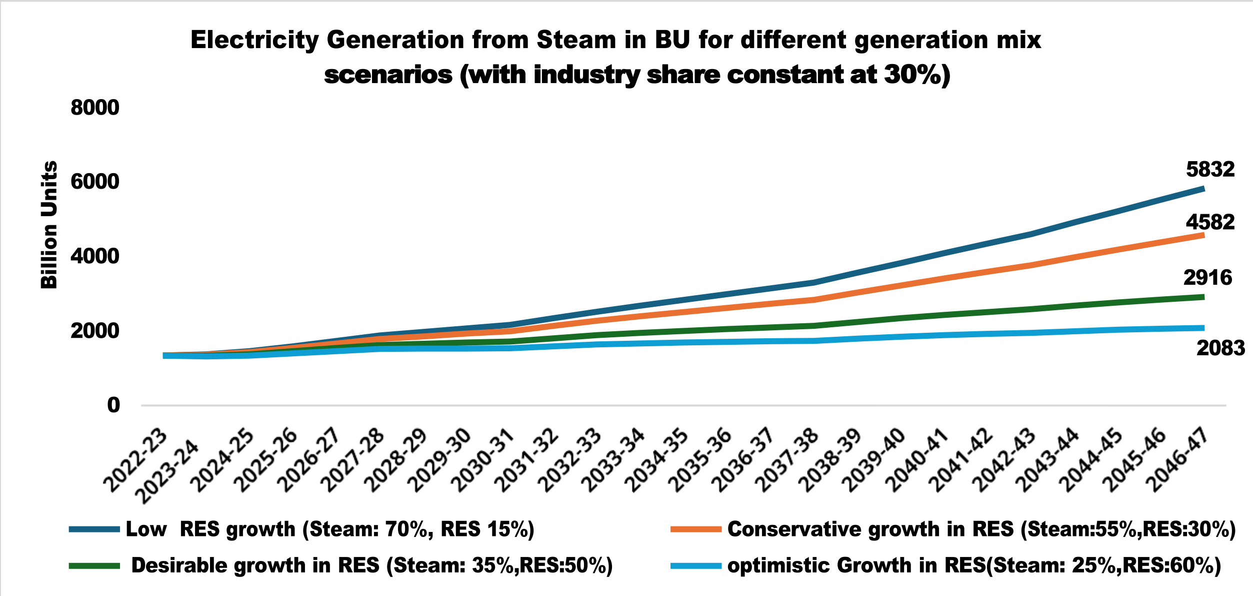

Figure 8: Electricity Generation from Steam when industry grows to 30% by 2047

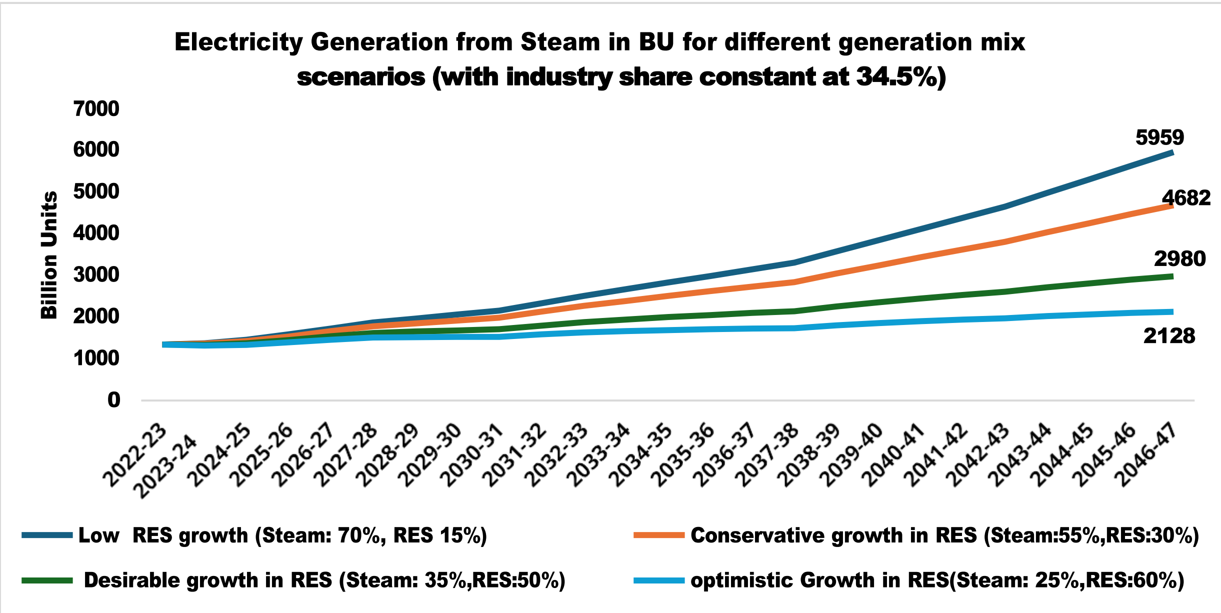

Figure 9: Electricity Generation from Steam when industry grows to 34.5% by 2047 Table 14:

Electricity Generation from Steam by 2047 across scenarios

Projected electricity generation from steam by 2047(BU)				
	Variation in the electricity generation mix#			
Share of industry in GDP	Low-RES growth (Steam: 70%, RES 15%)	Conservative growth in RES (Steam:55%, RES:30%)	Desirable growth in RES (Steam: 35%, RES:50%)	optimistic Growth in RES (Steam: 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 the generation is expected from Large Hydro/ Nuclear

Results show that gross electricity generation from steam-based sources by 2070 increases with the assumed steam share in the generation mix. At an 11% share, generation ranges from 2,946 BU under the 10% efficiency scenario to 2,783 BU under the 15% efficiency scenario. If the steam share remains at 25%, generation more than doubles to 6,696 BU (10% efficiency) and 6,324 BU (15% efficiency). While higher efficiency reduces coal-based generation marginally, this reduction is small compared to the increase driven by a higher steam share.

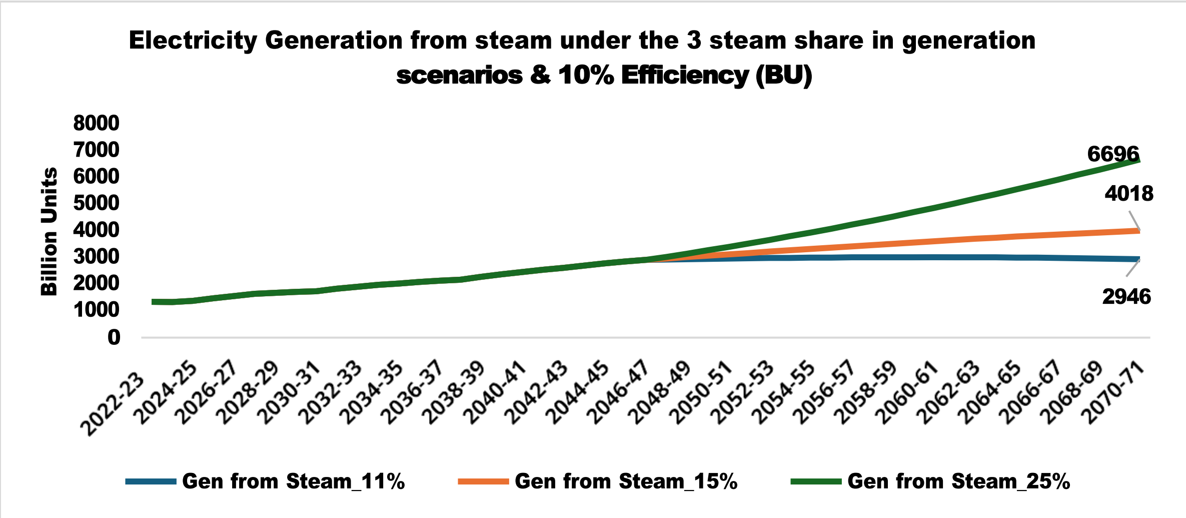

Figure 10: Electricity generation from steam by 2070 (10% efficiency)

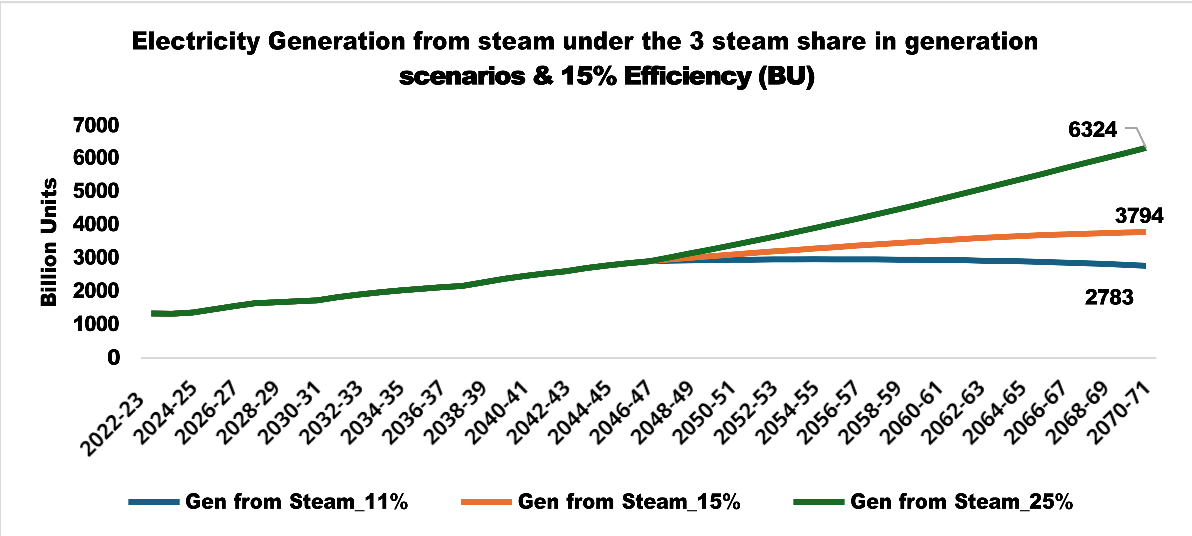

Figure 11: Electricity generation from steam by 2070 (15% efficiency) Table 15:

Electricity Generation from steam by 2070 across scenarios

Projected electricity generation from steam by 2070 (BU)	10% efficiency	15% efficiency
Steam share in generation: 11%	2946	2783
Steam share in generation: 15%	4018	3794
Steam share in generation: 25%	6696	6324

Thermal Coal Demand

Results show that India's thermal coal demand will rise[4] in absolute terms until at least 2047, regardless of renewable energy (RES) expansion. Even with 60% of electricity from RES, thermal power plants are projected to consume about 1,283 million tonnes of coal if industry's share reaches 34.5% of GDP and about 1,221 million tonnes if it remains at 27%. Both exceed the 2024 thermal coal consumption of 922.38 million tonnes.

Thermal coal demand may plateau in high-RES scenarios, but these depend on rapid deployment of advanced battery storage, which remains a technological and economic challenge. In an extreme scenario with about 70% RES in the generation mix, coal at 15%, and large hydro and nuclear at 15%, thermal coal demand could decline after 2047 to about 700 million tonnes. This would require nuclear capacity to reach 100 GW, pumped and solar storage to exceed 30 GW, and gas to rise above 10% of the generation mix and approach 15%.

In a more realistic scenario where coal contributes about 55% of electricity generation, thermal coal demand could increase to 2,687 million tonnes and 3,593 million tonnes under low and high industrial growth scenarios, respectively, more than double current consumption. These results indicate that although RES expansion may slow the growth rate of thermal coal demand, absolute demand is likely to continue rising until 2047.

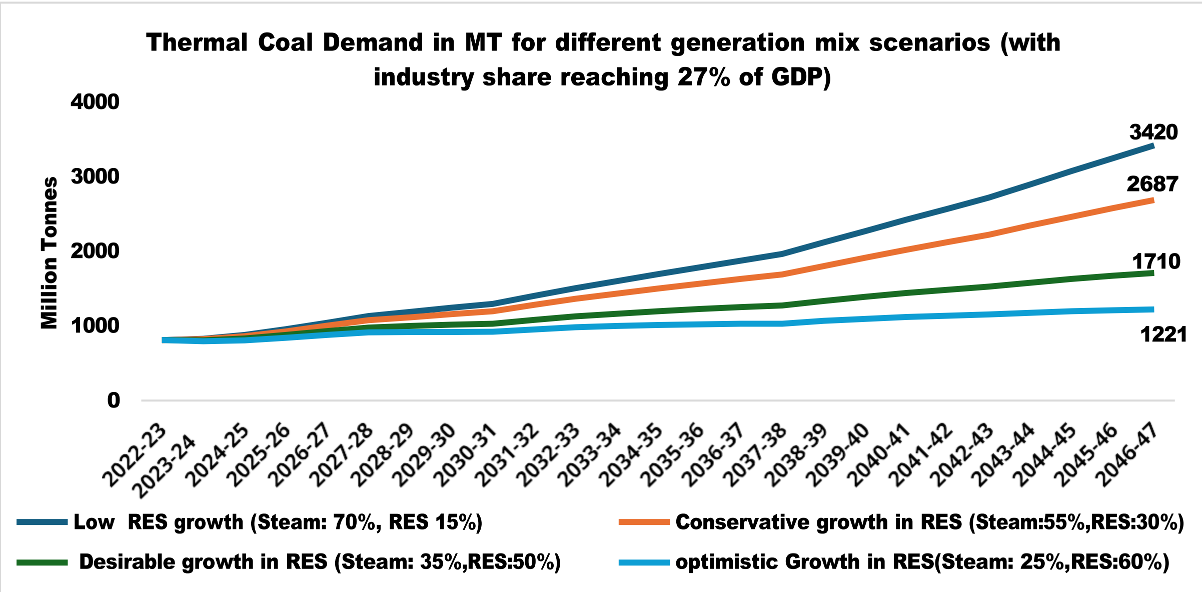

Figure 12: Demand for Thermal Coal when the share of industry grows to 27% of GDP by 2047

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[4] The rate of this rise is dependent on the parametric elasticities of each sector, which do not consider sector-specific load profile, costs, capacity constraints, transmission, and infrastructure bottlenecks. This, therefore, might lead to a tendency to show a higher rise than cost-optimisation-based models.

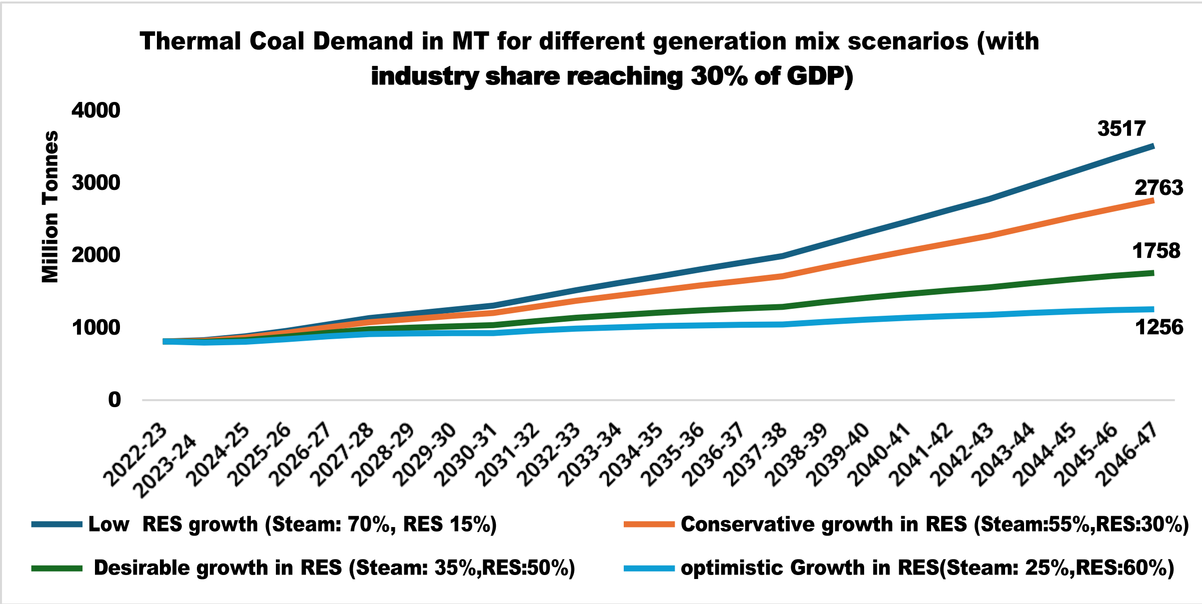

Figure 13: Demand for Thermal Coal when the share of industry grows to 30% of GDP by 2047

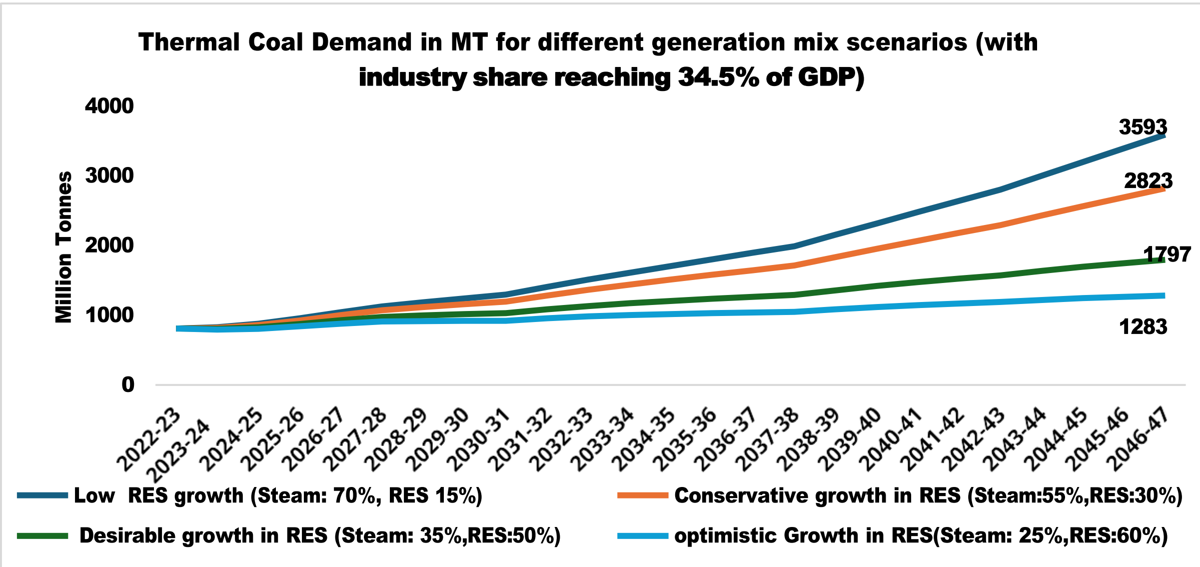

Figure 14: Demand for Thermal Coal when the share of industry grows to 34.5% of GDP by 2047

Table 16 : Projected demand of thermal coal by 2047

Projected Demand for Coal for electricity generation by 2047(Million tonnes)

	Variation in electricity generation mix			
Share of Industry 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

From a base of 1,758 MT in 2047, thermal coal demand varies widely as the share of steam in the generation mix declines along the Net Zero 2070 pathway. With a 25% steam share, demand reaches 4.03 BT by 2070 under the 10% efficiency scenario. If the steam share falls to 11%, demand drops to 1.77 BT. Under a higher efficiency assumption of 15%, demand still ranges from 3.8 BT to 1.68 BT as the steam share declines (see Table 17).

The efficiency improvements considered here are sectoral efficiency gains, meaning sectors require less electricity per unit of output rather than improvements in plant-level thermal efficiency. While this reduces electricity demand to some extent, demand by 2070 remains very high. Consequently, the share of steam-based generation has a much stronger influence on thermal coal demand than sectoral efficiency improvements alone.

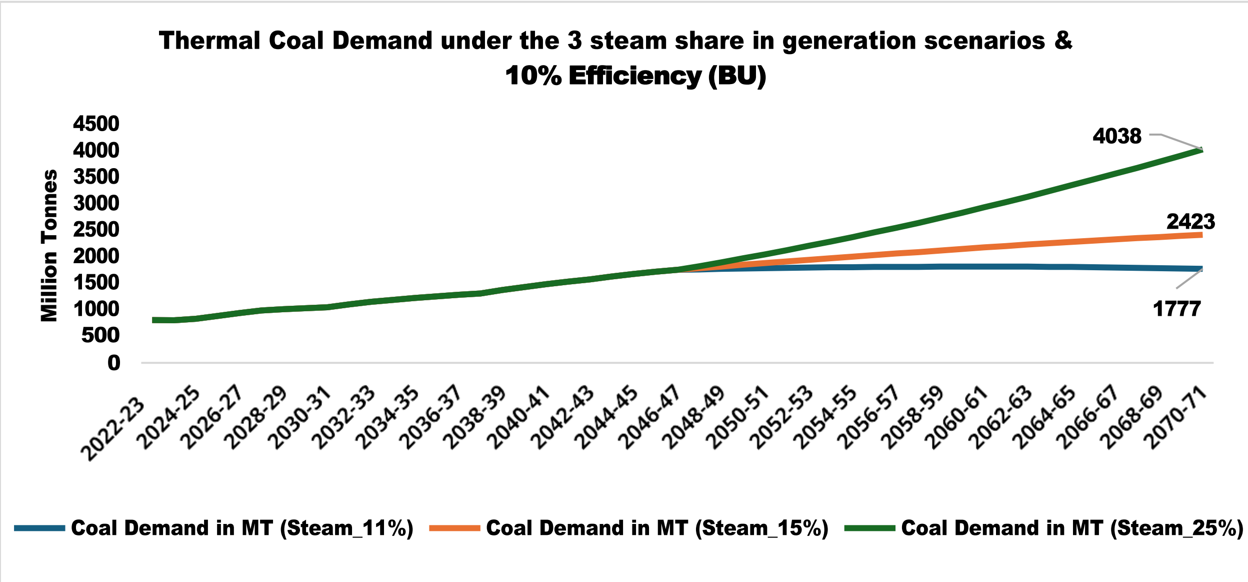

Figure 15: Thermal Coal Demand by 2070 (10% efficiency)

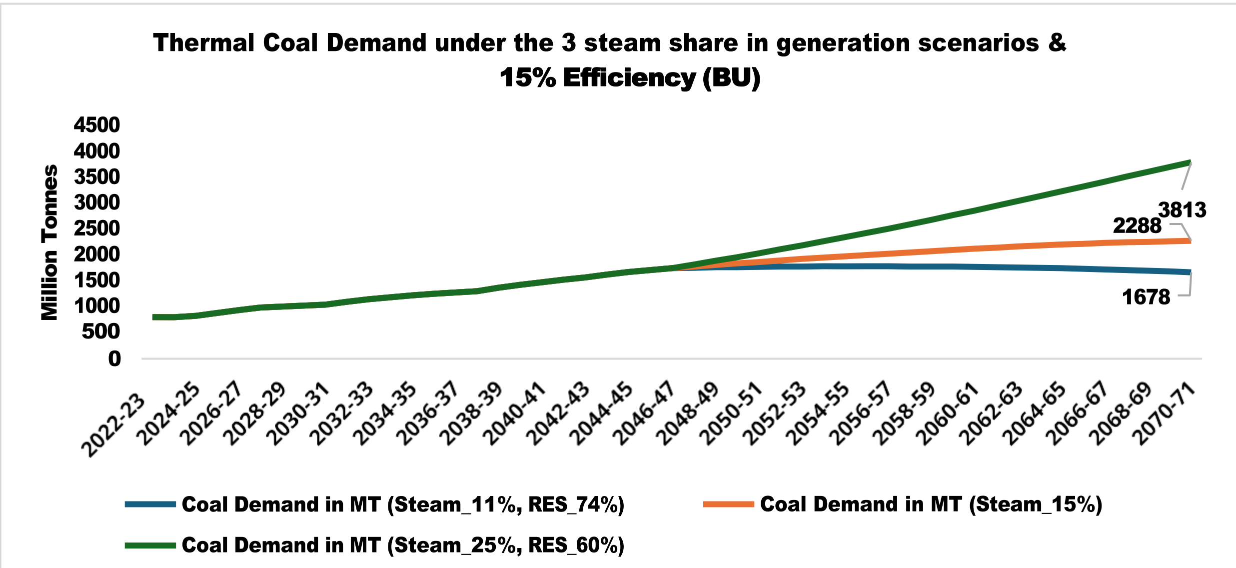

Figure 16: Thermal Coal Demand by 2070 (15% efficiency)

Table 17: Thermal Coal Demand by 2070 across scenarios

Projected thermal coal demand by 2070 (in MT)	10% efficiency	15% efficiency
Steam share in generation: 11%	1777	1678
Steam share in generation: 15%	2423	2288
Steam share in generation: 25%	4038	3813

Installed Capacity Requirements of Steam

Projections for coal-based thermal capacity by 2047 reflect the interaction between industrial growth and the generation mix. As industry's share in GDP rises from 27% to 34.5%, required thermal capacity increases from 1,077 GW to 1,132 GW under the low-RES growth scenario, where coal provides 70% of electricity generation.

Under the optimistic RES scenario with 60% RES generation, thermal capacity falls to 385 GW under low industrial growth and 404 GW under high industrial growth. These results show that even with aggressive RES deployment, substantial coal-based capacity will remain necessary for grid reliability and peak demand.

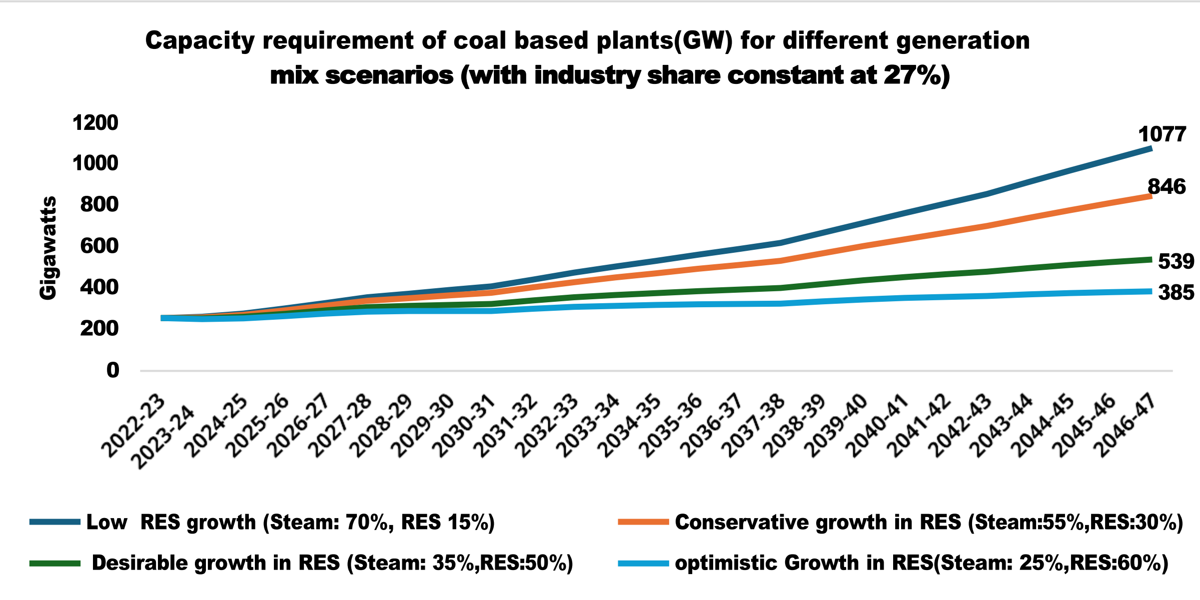

Figure 17: Steam Capacity requirements if the industry grows to 27% of GDP by 2047

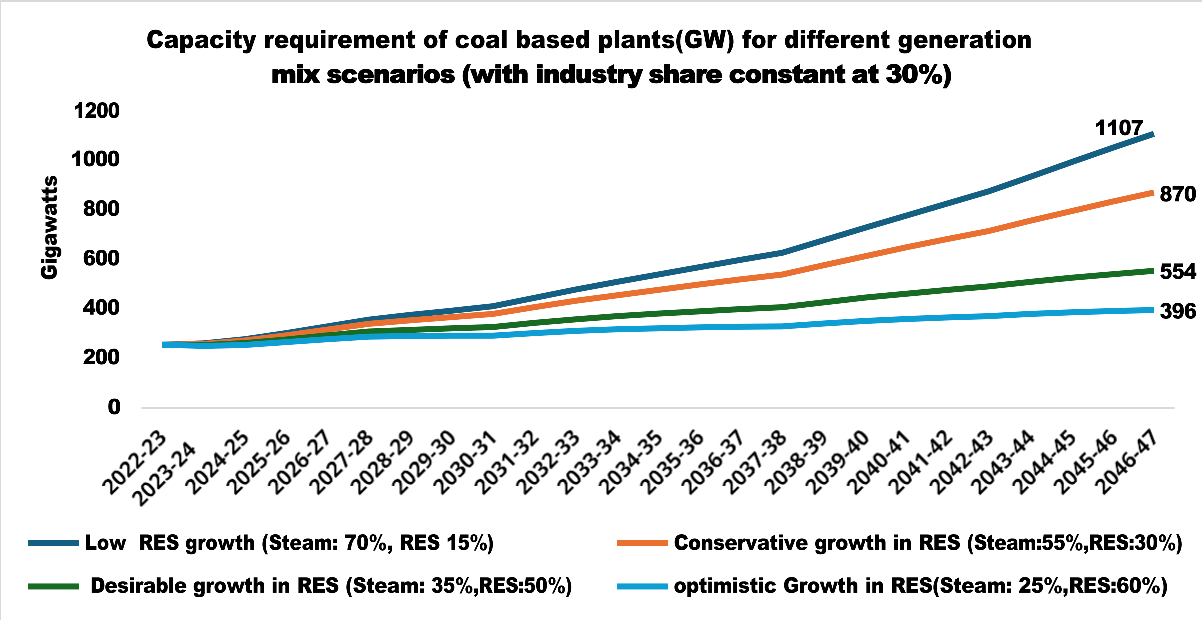

Figure 18: Steam Capacity requirements if the industry grows to 30% of GDP by 2047

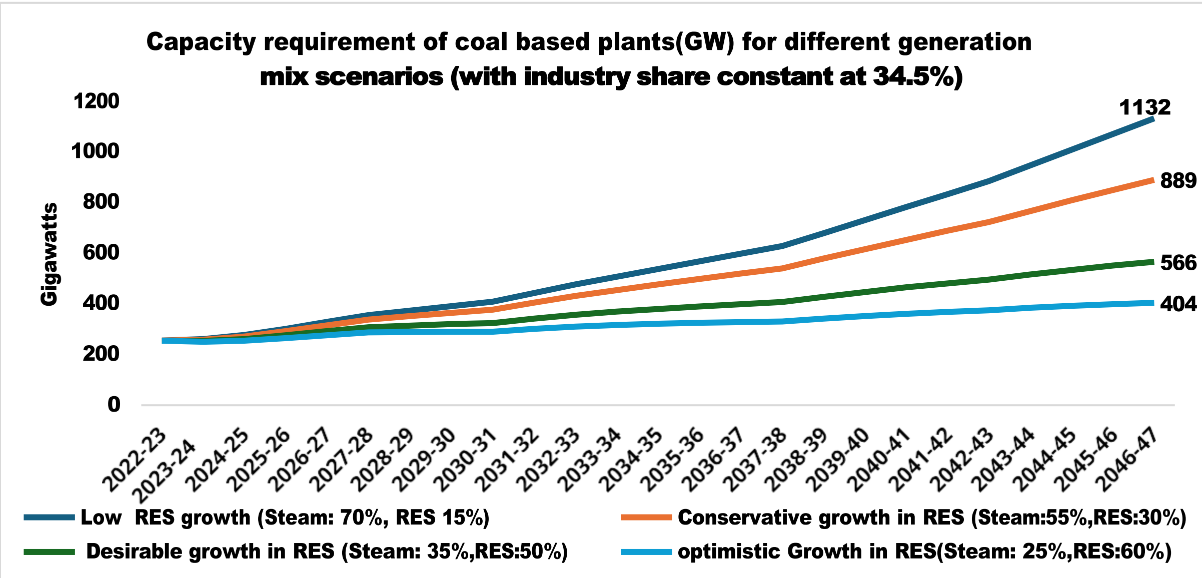

Figure 19: Steam Capacity requirements if the industry grows to 34.5% of GDP by 2047 Table 18:

Steam capacity requirements by 2047 under various scenarios

	Projected requirement for coal-based thermal capacity by 2047 (in GW)			
	Variation in the electricity generation mix			
Share of Industry 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

The table above shows that thermal power plant capacity could nearly double to 404 GW by 2047 under the Viksit Bharat industrial growth trajectory, even if coal's share in electricity generation falls from 70% to 25%. In a more realistic medium-term scenario with a 55% steam share, TPP capacity may rise to 846–889 GW as industry's share in GDP increases from 27% to 34.5%.

Projected steam-based installed capacity by 2070 increases with rising electricity demand from sustained economic growth. At an 11% steam share, required capacity ranges from 560 GW under the 10% efficiency scenario to 528 GW under the 15% efficiency scenario, well above the 2024 level of 243 GW. If the steam share reaches 25%, capacity more than doubles to 1,272 GW (10% efficiency) and 1,201 GW (15% efficiency). While efficiency improvements reduce capacity requirements, the reduction is modest compared to the increase driven by electricity demand and the generation mix.

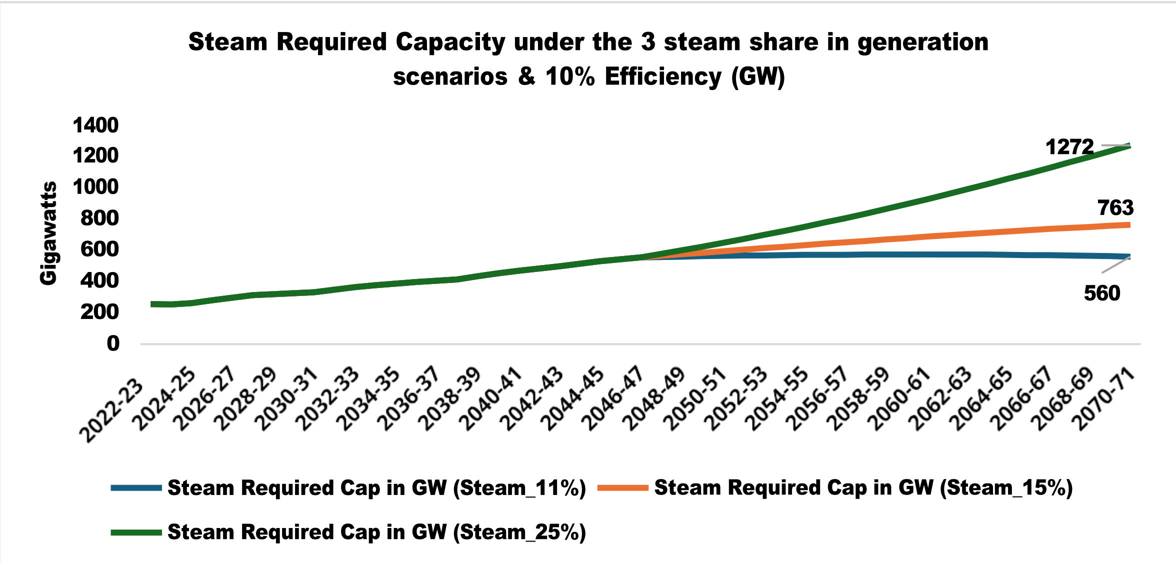

Figure 20 : Steam Capacity Requirement by 2070 (10% efficiency)

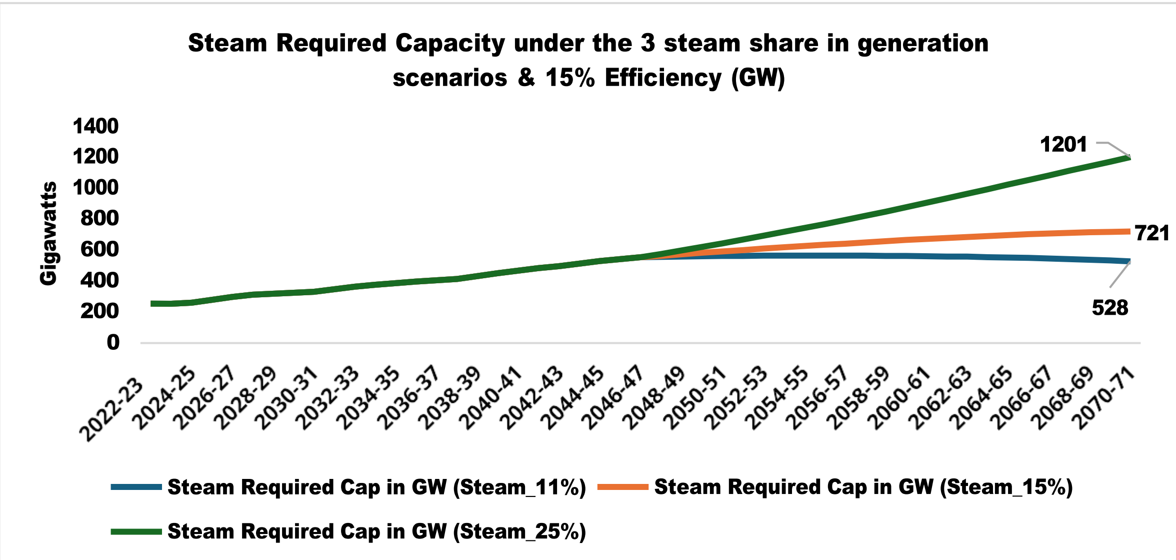

Figure 21: Steam Capacity Requirement by 2070 (15% efficiency)

Table 19: Steam Required Capacity by 2070 across scenarios

Projected steam required installed capacity by 2070 (in GW)	10% efficiency	15% efficiency
Steam share in generation: 11%	560	528
Steam share in generation: 15%	763	721
Steam share in generation: 25%	1272	1201

Generation from Renewable Energy Sources (RES)

The graphs illustrate the projected electricity generation from renewable energy sources (RES) by 2047 across different industrial growth scenarios and energy transition pathways. As shown, higher industrial share in GDP leads to a modest increase in renewable electricity generation due to rising electricity demand. However, the most significant variation arises from the assumed electricity generation mix. Scenarios with slower renewable expansion (higher steam share) show higher projected generation from RES in absolute terms, while scenarios with faster renewable penetration reflect a shift in the overall generation structure.

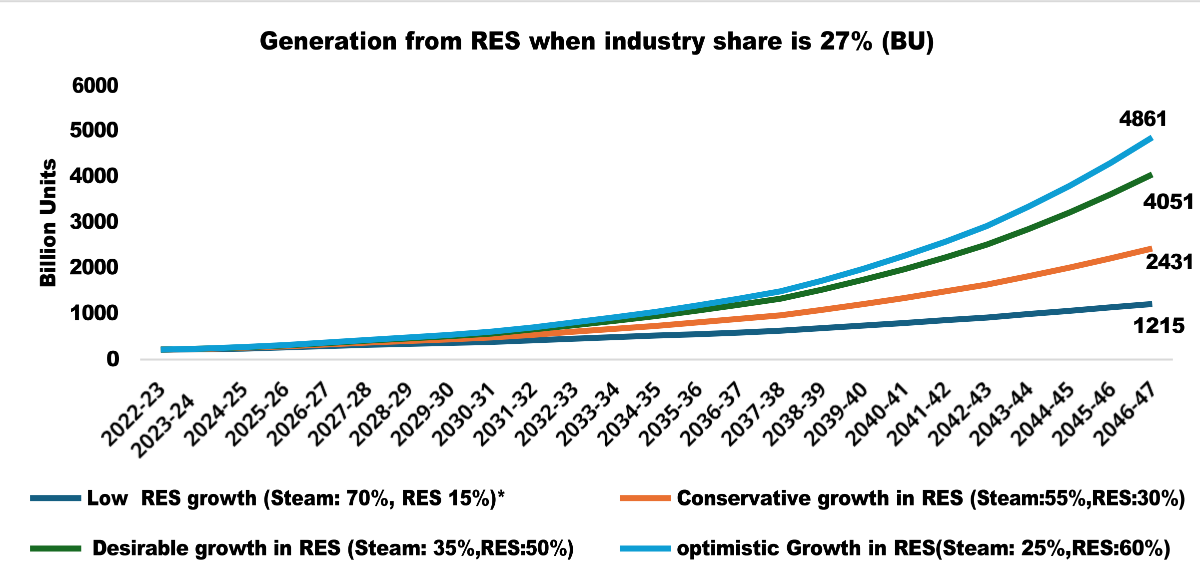

Figure 22: Generation from RES by 2047 when the industry grows to 27%

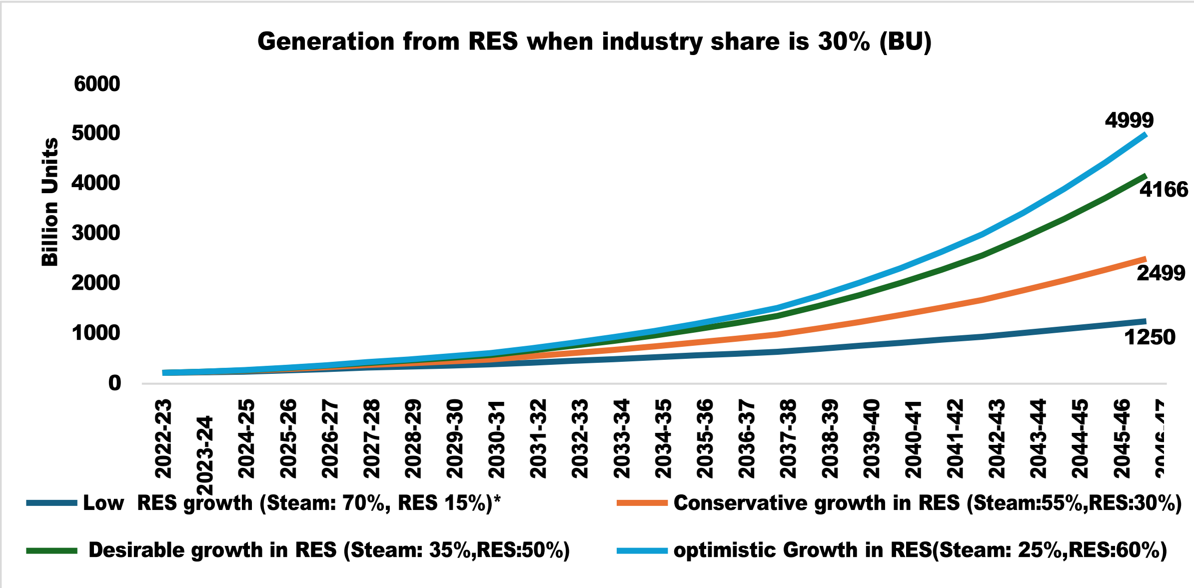

Figure 23: Generation from RES by 2047 when the industry grows to 30%

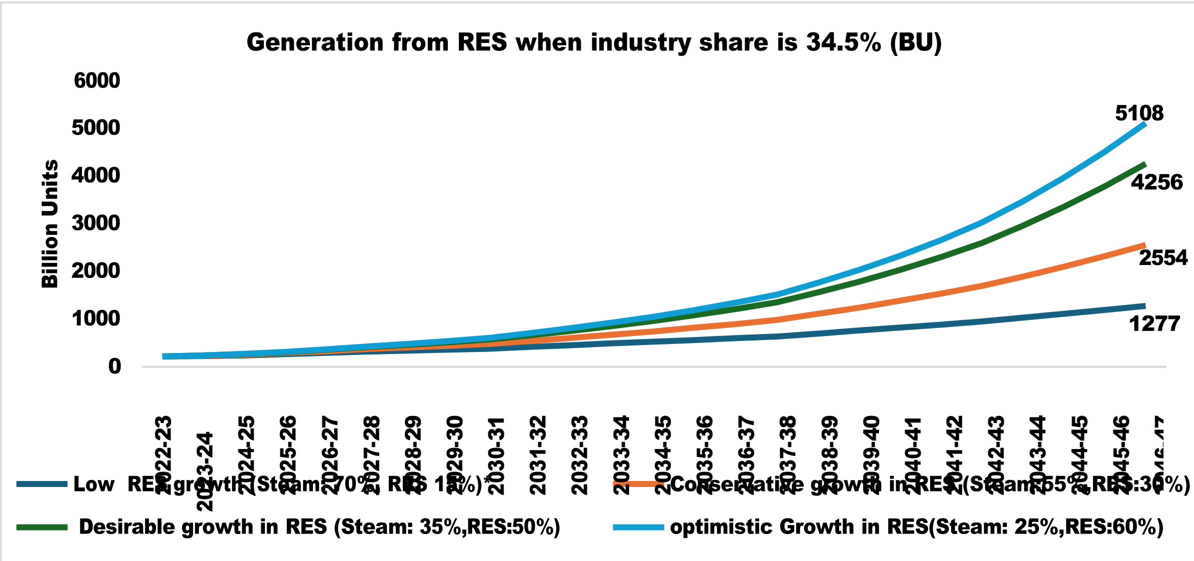

Figure 24: Generation from RES by 2047 when the industry grows to 34.5% Table 20:

Generation from RES by 2047 across scenarios

Projected electricity generation from RES by 2047(BU)				
	Variation in the electricity generation mix			
Share of industry in GDP	Low-RES growth (Steam: 70%, RES 15%)	Conservative growth in RES (Steam:55%, RES:30%)	Desirable growth in RES (Steam: 35%, RES:50%)	optimistic Growth in RES (Steam: 25%, RES:60%)
Low (27%)	4861	4051	2431	1215
Medium (30%)	4999	4166	2499	1250
High (34.5%)	5108	4256	2554	1277

Projected RES electricity generation by 2070 varies as the share of steam-based generation declines, reflecting shifts in the generation mix. At an 11% steam share, RES generation reaches 20,624 BU under the 10% efficiency scenario and 19,478 BU under the 15% efficiency scenario. If steam retains a 25% share, required RES generation falls to 16,874 BU (10% efficiency) and 15,937 BU (15% efficiency). These estimates incorporate both sectoral efficiency improvements and higher CUF for RES sources.

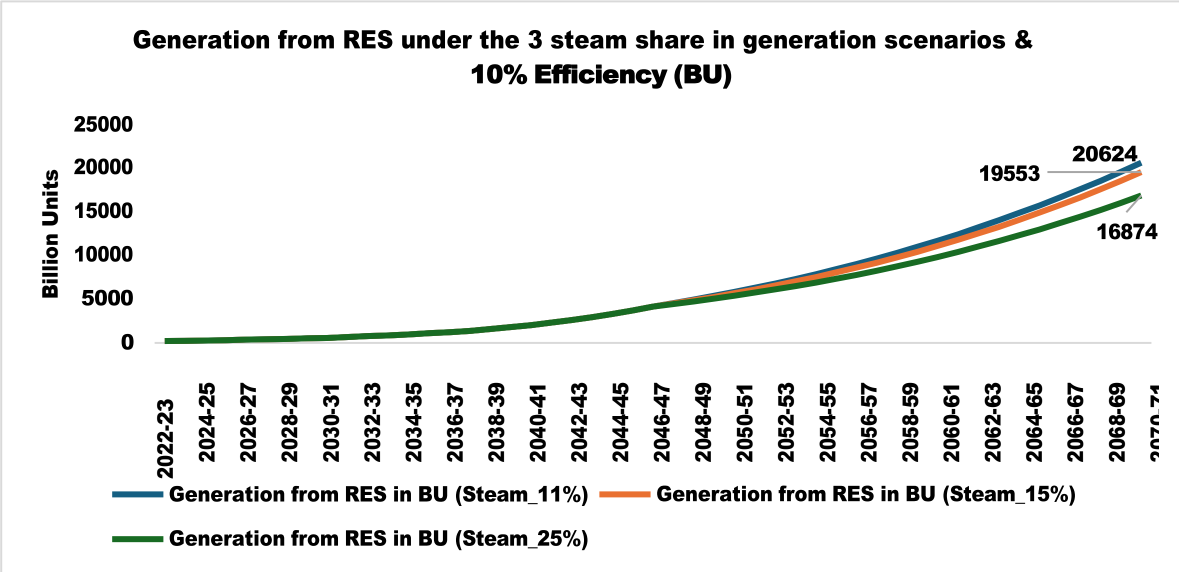

Figure 25: Generation from RES by 2070 (10% efficiency)

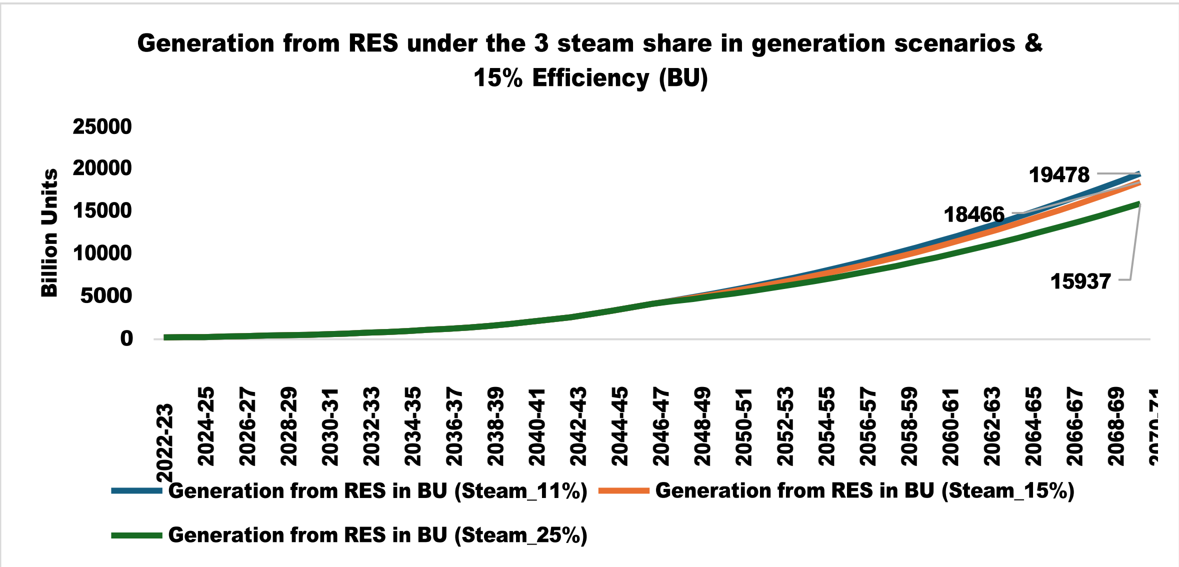

Figure 26: Generation from RES by 2070 (15% efficiency)

Table 21: Electricity Generation from RES by 2070 across scenarios

Projected generation from RES by 2070 (in BU)	10% efficiency	15% efficiency
Steam share in generation: 11%	20624	19478
Steam share in generation: 15%	19553	18466
Steam share in generation: 25%	16874	15937

Installed Capacity Requirements of Renewable Energy Sources (RES)

Projected RES capacity requirements by 2047 highlight the scale of infrastructure expansion needed under different generation mix pathways. As the share of RES increases, required capacity rises across all levels of industrial share in GDP.

In the conservative scenario, where RES contributes 30% of the generation mix, the required capacity ranges from about 730 GW to 767 GW. In the low-RES scenario with a 15% share, capacity ranges from about 365 GW to 384 GW. Under the optimistic scenario with 60% RES generation, the required capacity nearly quadruples to 1,461–1,535 GW.

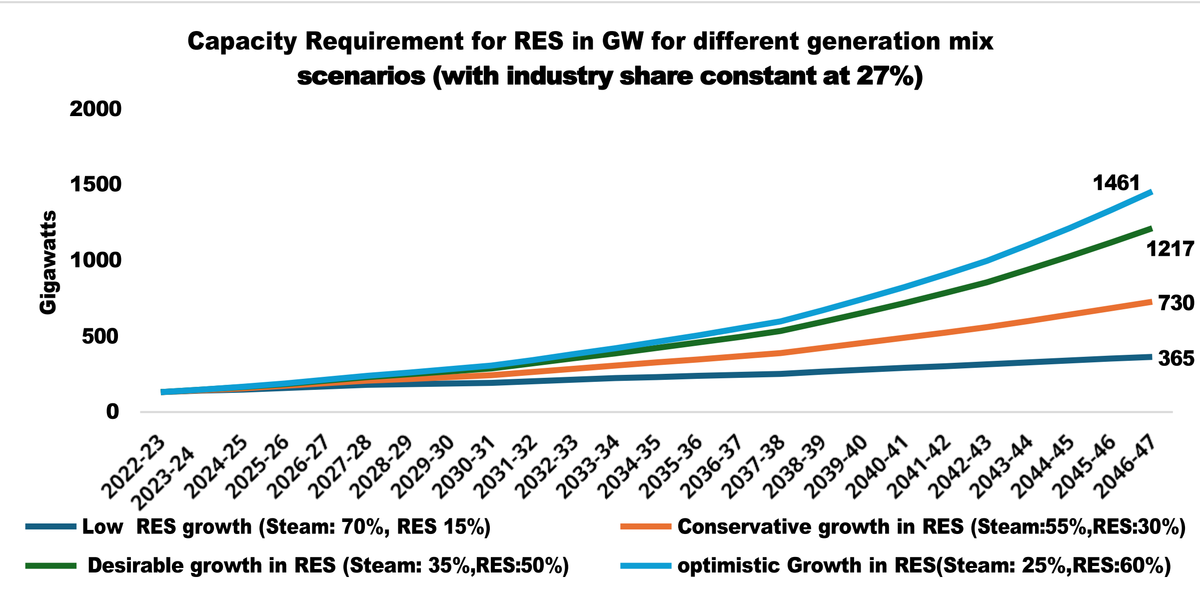

Figure 27: RES capacity requirement if the industry grows to 27% of GDP by 2047

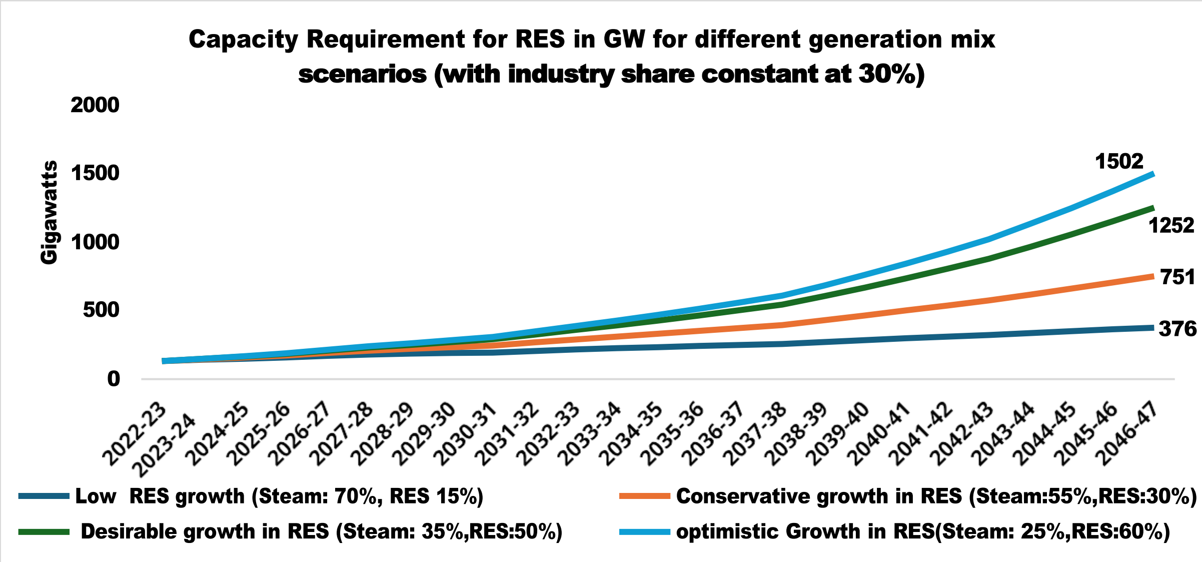

Figure 28: RES capacity requirement if the industry grows to 30% of GDP by 2047

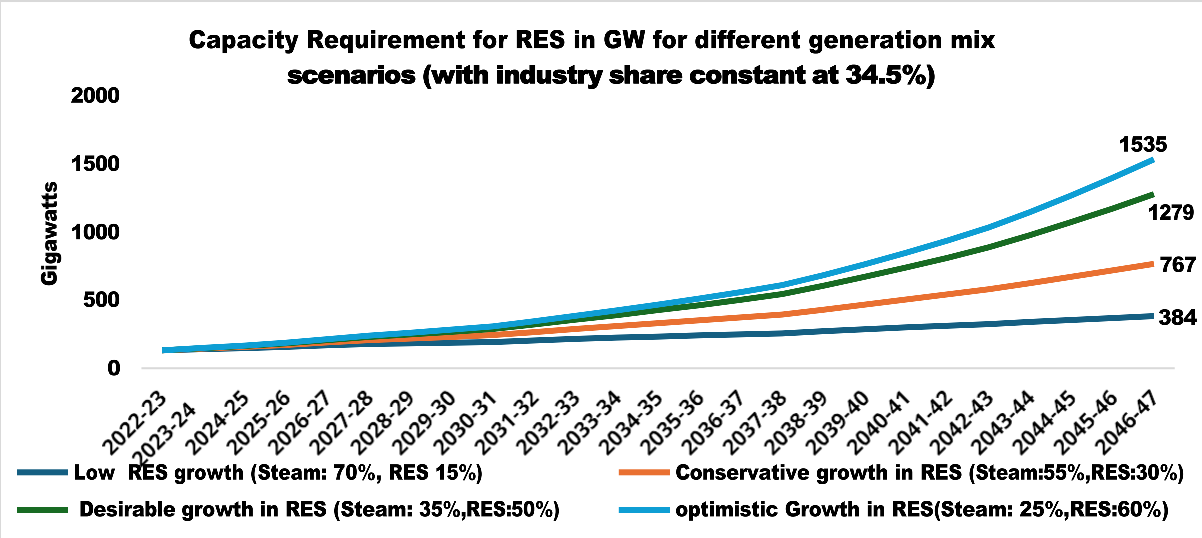

Figure 29: RES capacity requirement if the industry grows to 34.5% of GDP by 2047

Table 22: RES capacity requirements by 2047 under various scenarios

Projected capacity requirement for RES by 2047(GW)				
Variation in the electricity generation mix				
Share of Industry 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

These figures highlight the scale of investment and infrastructure needed for high-RES penetration, particularly in land, storage, and grid integration. They also emphasise the need for parallel expansion of transmission and storage to support these targets.

Projected RES installed capacity by 2070 shows an inverse relationship with the share of steam-based generation in the electricity mix. At an 11% steam share, RES capacity reaches 6,123 GW under the 10% efficiency scenario and 5,783 GW under the 15% efficiency scenario. If steam remains at 25%, the required RES capacity falls to 5,010 GW (10% efficiency) and 4,731 GW (15% efficiency). While higher efficiency reduces capacity needs, the main driver remains the generation mix between steam and RES.

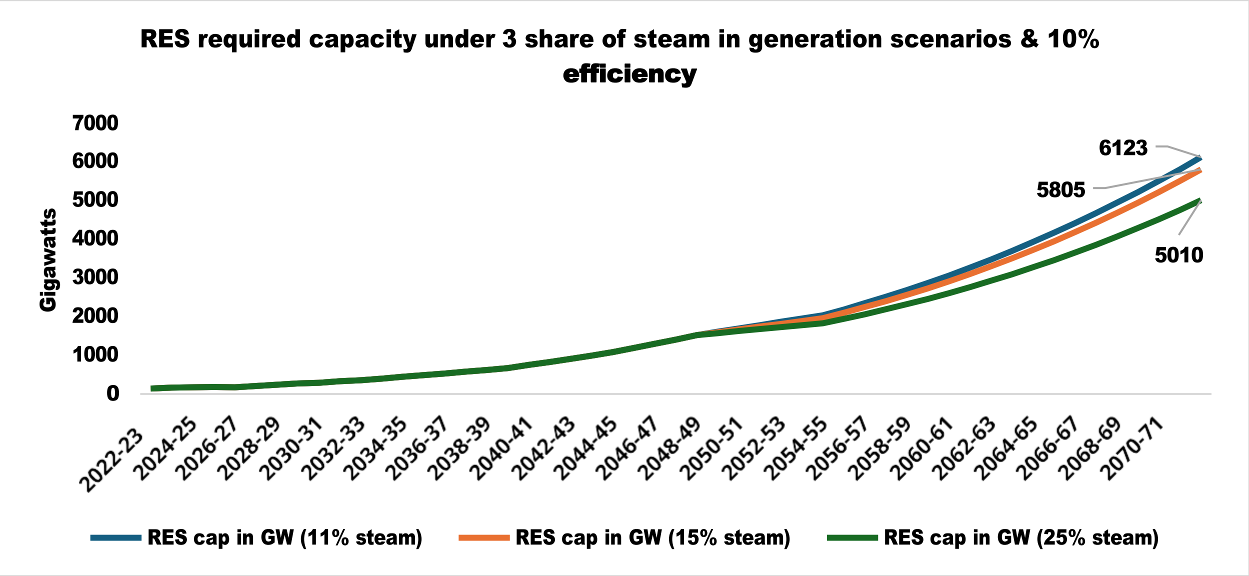

Figure 30: RES Capacity Requirement by 2070 (10% efficiency)

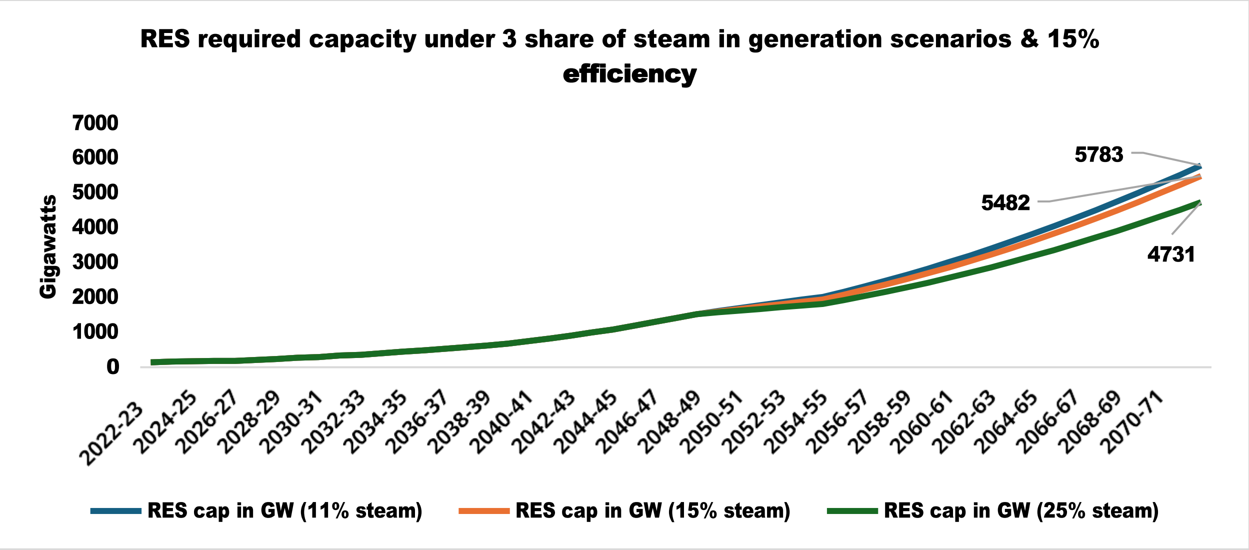

Figure 31: RES Capacity Requirement by 2070 (15% efficiency)

Table 23 : RES Required Capacity by 2070 across scenarios

Projected RES required installed capacity by 2070 (in GW)	10% efficiency	15% efficiency
Steam share in generation: 11%	6123	5783
Steam share in generation: 15%	5805	5482
Steam share in generation: 25%	5010	4731

Inferences, Validation and Limitations

The findings of the modelling exercise indicate that within the framework of Viksit Bharat@2047 and Net Zero@2070, India will witness sustained economic growth, a structural surge in electricity demand, and a continued, though evolving, role for coal in supporting electricity generation. The transition unfolds in a sequenced manner rather than through abrupt substitution.

Economic Expansion and the Scale of Electricity Growth

As India advances toward its Viksit Bharat vision, sustained economic expansion remains the primary driver of long-term electricity demand. With GDP projected to grow at approximately 7% CAGR until 2047 and moderate thereafter, India's transition toward high-income status significantly alters both the quantum and composition of energy consumption.

Electricity demand increases from 1,824 BU in 2022–23 to:

- 8,513 BU by 2047 (a 4.7-fold increase over the base year), and
- 26,784 BU by 2070 (nearly a 15-fold increase relative to 2022–23).

The slightly lower growth in electricity relative to GDP reflects gradual GDP–energy decoupling driven by efficiency gains and technological progress, making the projected trajectory macroeconomically consistent.

This scale of expansion reflects structural transformation rather than incremental growth.

Per Capita Electricity Consumption: Development Convergence

Per capita electricity consumption rises from approximately 1,395 kWh in 2022–23 to (refer to figure 34):

- 4,440 kWh by 2047, and
- 13,400–14,500 kWh by 2070 under the 10% and 15% post-2047 efficiency scenarios.

This represents nearly a ten-fold increase over the base year.

Per capita values refer to final electricity consumption, differing from generation that includes transmission, distribution, and auxiliary losses.

Efficiency	Share of steam in 2070	Parameter	2022-23 (Base year)	2029-30	2039-40	2046-47	2050-51	2055-56	2060-61	2065-66	2070-71
10% efficiency by 2070		Per capita electricity consumption (kwh)	1029	1564	2931	4439	5451	6957	8797	11261	14227
		Gross generation (BU)	1814	2882	5465	8331	10294	13267	16952	21439	26784
	25%	Generation from Coal (BU)	1342	1714	2379	2915	3406	4093	4875	5749	6696
	15%						3128	3379	3619	3836	4017
	11%						2970	3008	3020	3001	2946
	25%	Thermal Coal Demand (Million Tonnes)	810	1034	1435	1758	2054	2468	2940	3467	4038
	15%						1886	2038	2183	2314	2423
	11%						1791	1814	1821	1810	1777
	25%	Thermal Capacity Requirement (GW)	255	326	452	554	647	777	926	1092	1272
	15%						594	642	687	729	763
	11%						564	571	574	570	560
	25%	Generation from RES (BU)	218	524	1802	4166	5400	7344	9844	12995	16874
	15%						5678	8058	11100	14908	19553
	11%						5836	8429	11699	15743	20624
	25%	RES Capacity Requirement (GW)	177	334	827	1525	1726	2189	2926	3858	5010
	15%						1815	2402	3300	4426	5805
	11%						1866	2512	3478	4673	6123

Figure 32: Results for 10% efficiency scenario

Efficiency	Share of steam in 2070	Parameter	2022-23 (Base year)	2029-30	2039-40	2046-47	2050-51	2055-56	2060-61	2065-66	2070-71
15% efficiency by 2070		Per capita electricity consumption (kwh)	1029	1564	2931	4439	5428	6878	8607	10857	13436
		Gross generation (BU)	1814	2882	5465	8331	10251	13116	16585	20670	25296
	25%	Generation from Coal (BU)	1342	1714	2379	2915	3392	4046	4770	5542	6324
	15%						3115	3341	3541	3699	3794
	11%						2958	2974	2955	2893	2782
	25%	Thermal Coal Demand (Million Tonnes)	810	1034	1435	1758	2046	2440	2877	3342	3813
	15%						1879	2015	2135	2231	2288
	11%						1784	1793	1782	1745	1678
	25%	Thermal Capacity Requirement (GW)	255	326	452	554	644	768	906	1053	1201
	15%						592	634	672	702	721
	11%						562	565	561	550	528
	25%	Generation from RES (BU)	218	524	1802	4166	5377	7260	9631	12529	15937
	15%						5654	7966	10860	14373	18466
	11%						5811	8333	11447	15178	19478
	25%	RES Capacity Requirement (GW)	177	334	827	1525	1719	2164	2863	3719	4731
	15%						1808	2374	3228	4267	5482
	11%						1858	2484	3403	4506	5783

Figure 33: Results for 15% efficiency scenario

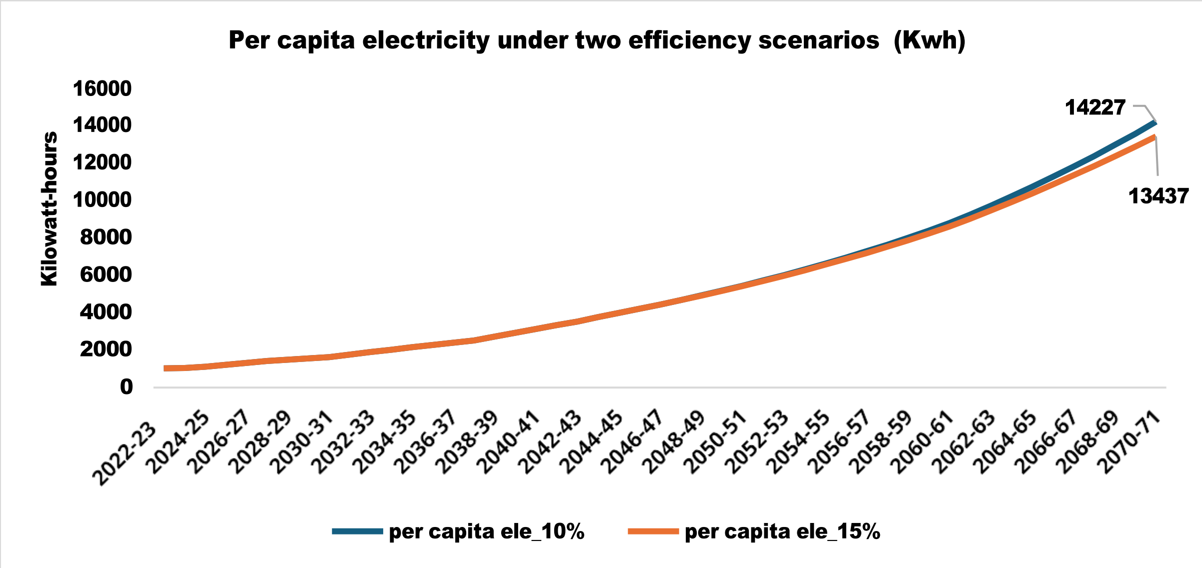

Figure 34: Per capita electricity consumption by 2070 across scenarios

Benchmarking

In an internal ACPET benchmarking exercise, per capita electricity consumption was estimated under different assumptions. India was assumed to reach China's current per capita electricity consumption level of 7,302 kWh by 2060 and increase further to 10,000 kWh by 2070. Two alternative generation mix pathways were considered for 2070: one with a 50% share of renewable energy sources (RES) in total generation (steam: 35%, others: 15%), and another with a 70% RES share (steam: 15%, others: 15%). The analysis also assumed auxiliary consumption of 4.5% and transmission and distribution losses of 6% by 2070, along with a coal demand factor of 0.603 kg per kWh.

Under these assumptions, projected thermal coal demand by 2070 ranged between 1,703 MT and 3,973 MT, depending on the RES penetration scenario (refer to Figure 35). Although per capita electricity consumption in this benchmarking exercise was lower than the present model's endogenous projections of approximately 13,000–14,500 kWh by 2070, thermal coal demand remained substantial, highlighting the sensitivity of thermal coal requirements to generation mix assumptions rather than per capita electricity levels alone. For comparison, NITI Aayog's Net Zero scenario[5] projects per capita electricity consumption of approximately 10,000 kWh by 2070.

[5] NITI Aayog, *Scenarios towards Viksit Bharat and Net Zero: An Overview, Vol. 1*, Government of India, 2026

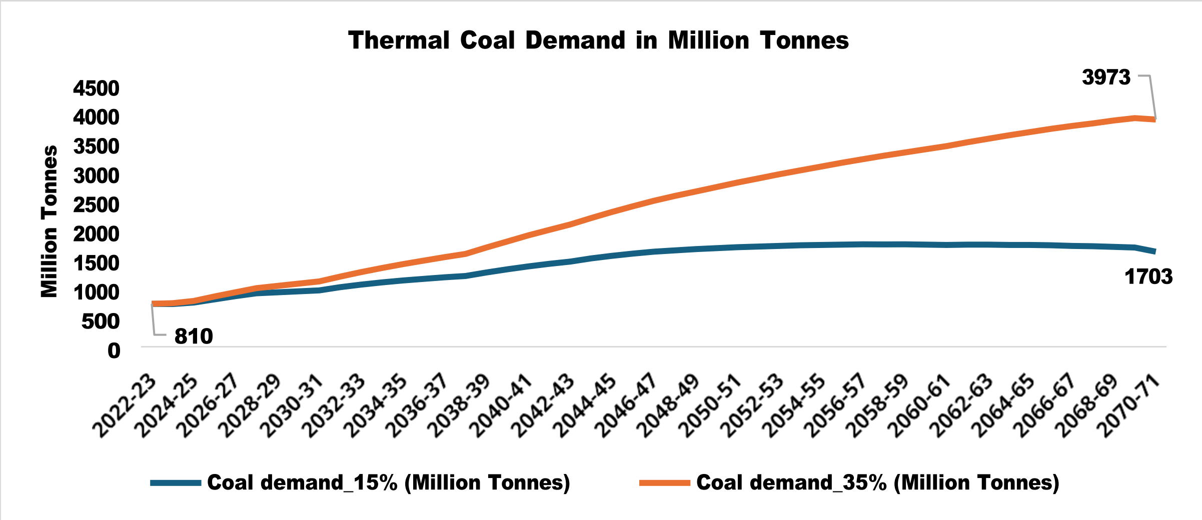

Figure 35: Thermal Coal Demand if per capita electricity consumption reaches 10000 kWh by 2070 under two different scenarios of RES growth (50% and 70%)

As of 2024, India consumes roughly 1,395 kWh per capita[6], compared to a global average of approximately 3,474 kWh per capita[7]. This substantial gap reflects latent demand driven by rising incomes, urbanisation, electrification of mobility, appliance penetration, cooling demand, digitalisation, and structural industrial expansion. Hence, the rising per capita electricity consumption scenario is an expected outcome.

Electrification as the Core Structural Driver

Electricity demand growth is not purely income-driven but structurally anchored in economy-wide electrification.

a) Transport Electrification

EV sales increased from 0.5 lakh units in 2016 to over 21 lakh units in 2024, with two- and three-wheelers accounting for nearly 90% of total sales (NITI Aayog, 2025)[8]. Electricity consumption at public charging stations rose from approximately 320 million units (April–December 2023) to about 590 million units (April–December 2024), marking an 84.65% year-on-year increase (CEA, 2025)[9].Although EV charging currently accounts for only about 0.2% of total electricity consumption (IEA, 2024)[10], it represents a potentially rapid load segment in the years to come.

b) Digital Infrastructure

India hosts approximately 271 data centres (Statista, 2025)[11]. These consumed around 13 TWh in 2024 (S&P Global, 2025)[12]. IT load capacity stood at 1.4 GW in 2025 and is expected to double in

[6] Ministry of Power, "India Successfully Met an All-Time Maximum Power Demand of 250 GW during FY 2024–25," Press Information Bureau, January 1, 2025.
[7] International Energy Agency, Electricity – World, 2023.
[8] NITI Aayog, *Electric Vehicles in India: Accelerating the Transition* (2025).
[9] *Pan-India electricity consumption by EV charging stations hits 590 MU in April–December FY25, The Hindu BusinessLine*, February 3, 2026.
[10] International Energy Agency (IEA), *Global EV Outlook 2024* (2024).
[11] Statista, "Number of Data Centres in India as of 2025," Statista Market Insights (2025).
[12] S&P Global Market Intelligence, *India Data Centre Market Outlook 2025* (2025).

the next two years. Unlike conventional commercial loads, AI-oriented data centres operate continuously and demand high reliability, increasing structural electricity intensity.

c) Residential and Industrial Electrification

Rising cooling demand, increasing appliance penetration, green hydrogen integration, and industrial electrification in steel, cement, chemicals, and manufacturing further reinforce structural electricity demand growth. The CAGR of electricity demand across historical and projected periods is summarised in the table below.

Table 24: CAGR of electricity demand (Historical and Projected)

CAGR of electricity demand (Historical and Projected)

Year	10% efficiency scenario	15% efficiency scenario
2012-2013 to 2022-23	5.20%	
2023-2024 to 2046-2047	6.75%	
2047-2048 to 2070-2071	4.95%	4.71%

Electricity demand growth remains elevated through 2047 before moderating post-2047 with expected efficiency improvement in consumption.

Thermal Coal, RES, and System Transformation Under a Net-Zero Constraint

Despite rapid renewable energy sources (RES) expansion, a complete thermal coal phase-down within the projected timeframe remains technically challenging. Model results show thermal coal demand rising from 809.5 MT in 2024 to 1,758.2 MT by 2047, plateauing and gradually declining after the mid-2050s to around 1,677 MT by 2070, even under an extremely aggressive increase in the share of RES in generation that reduces coal's share to roughly 11%. The trajectory reflects a two-phase transition. In the first phase (2024–2045), rapid economic expansion, electrification, and rising electricity demand require coal to remain the primary baseload source while RES expands to around 50% of generation. In the second phase (post-2045), improvements in RES capacity utilisation, grid integration, and storage technologies slow coal demand growth and gradually reduce its role. However, even with RES penetration exceeding 70%, coal plants are likely to retain a residual but critical role in grid stability, providing ancillary services such as frequency regulation, voltage support, spinning reserve, system inertia, and evening ramping. Current grid dynamics already reflect this pattern. Hydropower performs much of the daytime balancing during high solar generation, while coal ramps up to meet evening demand peaks, with gas contributing only marginally. This suggests that coal's role evolves from primary generation toward reliability and balancing services rather than disappearing abruptly.

RES expansion is nevertheless transformative, reaching roughly 77% of generation with installed capacity exceeding 5,800 GW by 2070. This implies RES generation of about 19,000 TWh, equivalent to 3.28 TWh per GW, compared with the current global ratio of roughly 2.22 TWh per GW[13] from about 9,900 TWh generated by 4,448 GW in 2024, indicating a significant improvement in effective utilisation. At the national level, this corresponds to an increase in average RES capacity utilisation.

[13] This ratio takes into consideration Large Hydro. (Source: International Energy Agency, 2024)

from roughly 12% in 2023 to around 35% by 2070, driven by solar–wind hybridisation, geographic diversification, and 4–12-hour grid-scale storage, which allows surplus daytime generation to be shifted to evening demand peaks and makes RES partially dispatchable. Although coal currently maintains much higher utilisation at about 6.018 TWh per GW, the gap narrows significantly as storage and grid integration improve. By 2070, the system is characterised by electricity demand approaching 26,784 BU, high-RES penetration, lower coal capacity factors, and widespread electrification across sectors. The transition unfolds sequentially through rapid demand growth, large-scale RES deployment, declining storage costs, and a gradual coal peak and tapering rather than abrupt substitution. Structurally, this trajectory reflects rising electricity demand associated with higher incomes, electrification across transport and industry, and infrastructure lock-in during industrialisation. Policy priorities, therefore, include accelerating RES and storage deployment, strengthening grid infrastructure and ancillary service markets, managing a gradual coal transition rather than an abrupt phase-down, and expanding flexible balancing capacity such as gas and hydro. In this evolving system, coal provides near-term reliability, RES diversification strengthens long-term resilience, and storage becomes central to maintaining system stability while enabling deep decarbonisation.

Validation & Benchmarking

Projections are validated against datasets and planning frameworks, including NITI Aayog's IESS Model V3, MNRE renewable targets, and CEA demand forecasts. A recent NITI Aayog report under the *Scenarios towards Viksit Bharat and Net Zero*[14] projects India's electricity demand to reach 6.5–8.1 trillion units by 2050. Under its net-zero scenario, RES accounts for ~80% of generation by 2050, significantly higher than the 60% RES share assumed in this study. Despite this higher RES penetration, the report still projects thermal coal demand of about 1,795 MT by 2050, broadly consistent with this study's estimate of 1,784–1,791 MT, reinforcing the continued role of coal alongside rapid RES expansion.

The recently issued draft National Electricity Policy projects 66% non-fossil generation by 2047, compared with 75% assumed in the optimistic scenario used here.

Study limitations

a) The model assumes a fixed electricity–GDP elasticity to isolate growth effects on electricity demand, although real-world elasticity may evolve due to technological progress and efficiency improvements.
b) Sectoral shares of GDP for agriculture, industry, and services are assumed to remain constant from 2047 to 2070.
c) Coal-based electricity generation assumes a conversion factor of 0.605 kg coal/kWh, based on 2023 averages, which is held constant through 2070 despite potential efficiency improvements from higher-grade coal and supercritical/ultra-supercritical technologies.

[14] NITI Aayog, *Scenarios towards Viksit Bharat and Net Zero: An Overview, Vol. 1*, Government of India, 2026

Source: ACPET; Shopkeeper from Rajhara, Jharkhand

Socioeconomic Implications of Coal Phase-Down – In the Backdrop of Viksit Bharat by 2047 and Net Zero by 2070

The quest to determine the trajectory of demand for Coal by 2047 and 2070 is not limited to modellers, policymakers, and administrations. It is perhaps more important for the driving force of the coal economy- the labour.

The ACPET Macroeconomic Coal Model and the latest NITI Aayog Net Zero reports both conclude that India's coal dependence is here to stay in the short- to medium-term. Hence, the path towards Net Zero 2070 for India will be marked by a critical balance between short- and medium-term energy security strategies and long-term climate mitigation and development goals. Any coal phase-down beyond 2055 (as per the ACPET Coal Macroeconomic Model) can also have multifarious repercussions for communities and the coal economy that depend on the value chain of thermal coal, from mining in coal-abundant states like Odisha, Chhattisgarh, Jharkhand, and Madhya Pradesh, to its use in thermal power plants.

Employment generation in Coal: Profiling the Coal workforce

The thermal coal mining sector and its entire value chain have been a labour-intensive industry, playing a crucial role in the employment generation of millions of workers in coal mining, transportation, and associated industries. Over 69 per cent of all coal mines are open-cast mines, where at least 25 per cent of the total workforce in the coal sector is directly employed[15]. A projected phase-down of coal beyond 2055 will have significant implications, with the burden falling primarily on semiskilled and unskilled workers.

[15] "India's Coal Phasedown Needs a Balanced Socio-Economic Framework," The Diplomat, April 2025.

While the RES sector is anticipated to replace coal in meeting energy demand, it does not offer the same level of employment intensity. Unlike coal mining, RES, particularly solar and wind, relies more on technology, automation, and intermittent maintenance, leading to lower employment opportunities post-installation.

Given the rise in coal production alongside the decline in employment, the output per worker in the coal sector has increased exponentially over the past 44 years. (Refer Figure 36 and 37). This can be attributed to the adoption of more efficient and advanced mining technologies, which enhance productivity while reducing labour intensity. With continued technological advancements, such as automation, AI-driven resource optimisation, and mechanised mining, per-worker output is expected to increase further. As mining operations become more digitised, the sector will likely continue this trend of higher productivity with a smaller workforce, leading to a likelihood of future job losses in the coal sector, despite a rise in coal production.

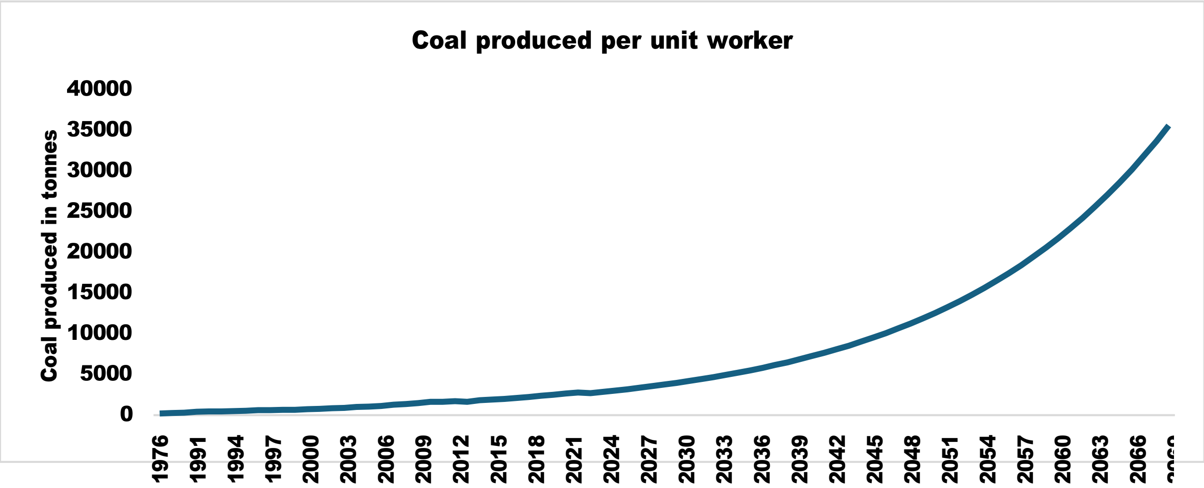

Figure 36 : Coal production per unit worker projected using historic data [16]

(Source: ACPET Estimates)

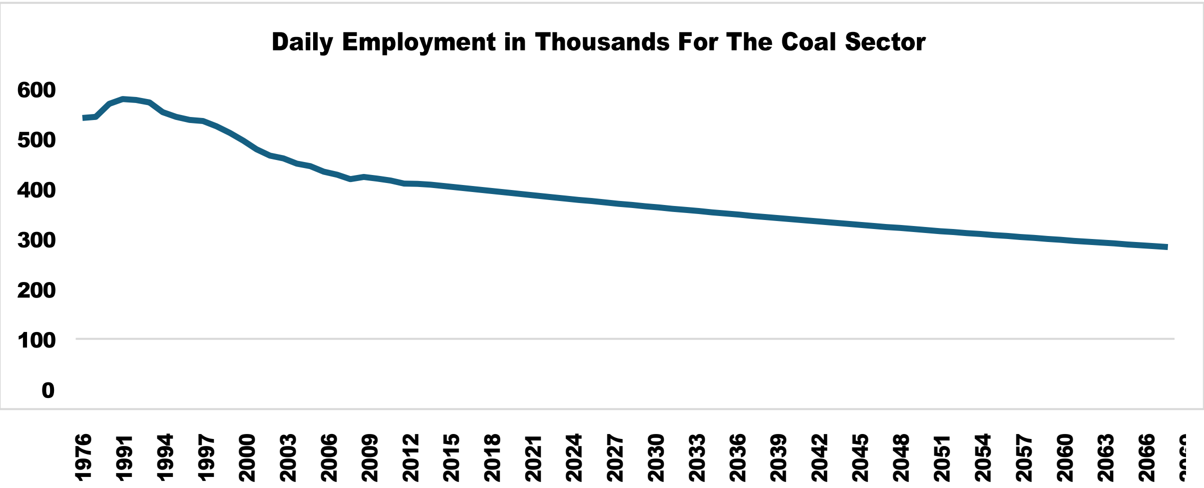

Figure 37: Projected employment trend in the coal sector given the technological development [17]

(Source: ACPET Estimates)

[16] Central Electricity Authority, General Review 2023-24, Ministry of Power, Government of India, 2024

[17] Central Electricity Authority, General Review 2023-24, Ministry of Power, Government of India, 2024

The Ashoka Centre for a People-Centric Energy Transition's (ACPET) macroeconomic modelling exercise indicates that the employment multiplier effect of coal-based thermal capacity is 1.13. This may worsen as labour productivity improves. The multiplier effect of renewable energy on employment is 1.12. Therefore, if one unit of coal-based thermal power capacity is replaced by one unit of renewable-based capacity, there will be a net decrease in employment in the economy of more than 0.01. Further, an increase in green job creation does not automatically translate to employment for coal workers due to skill differences. Addressing the needs of the coal workers would require targeted policies and programs on reskilling, training, relocation, and labour rehabilitation to avoid welfare loss in the coal economy.

Addressing the informalization of Labour in the coal economy:

It is evident that when discussing the coal phase-down in India, job losses and informalisation are major concerns. These workers from the coal sector need to be protected through social safety measures, or they will migrate or increase informalisation if they are not skilled enough to be absorbed into other similar and associated sectors. The state of Odisha has created an integrated planning process to address the possible future informalisation through requisite skilling and reskilling.

However, informal workers in the coal sector are not sufficiently covered by the social safety net. Many informal workers are employed in hazardous, exploitative conditions because of limited regulatory oversight. The Code on Social Security for workers in India, for the most part, borrows directly from the UWSSA and does not detail the scope, nature, or funding mechanisms of the social security schemes for informal coal workers in the coal economy.

The best thing India can adopt is the creation of a code on social security for informal workers of the coal economy through frequent national labour conferences related to coal phase-down impacts on the labour and other associated sectors, so that policymakers and the concerned stakeholders would be aware of the necessary policy changes that need to be implemented. Many developed countries are also successfully implementing labour policies and social security measures, including minimum wage policies.

Social Security*:* According to Article 22 of the Universal Declaration of Human Rights, "Everyone, as a member of society, has the right to social security," and social security is a fundamental human right. Approximately 90% of workers in India's labour market were employed informally in 2018–2019[18]. The current labour laws, social protection programs, and other employment benefits either do not cover these workers at all or do so only insufficiently. In India, the Government of India (GoI) established the National Commission for Enterprises in the Unorganised Sector (NCEUS) in 2004 to examine in depth the problems faced by businesses in the informal sector and offer solutions. The report asserted the need for social security and argued that it would act as a shock absorber during socio-economic shocks.

As a result, many initiatives have been launched to provide comprehensive social protection for informal workers. If we look at the statistics regarding the promotion of social security in terms

[18] Periodic Labour Force Survey (PLFS) 2018–19

of the availability of any social security, eligibility for paid leave, and having a written job contract (Table 25) for the informal sector, it is hardly more than 30%, which is significantly less. This is a startling position and needs to be kept in mind while designing social security benefits for any worker who might be affected by the coal phase-down in India, as the coal economy centres on the majority of the informal sector.

Table 25 : Informal workers with social security benefits

All India	Availability of social security benefits (%)	Eligibility for paid leave (%)	Has written job contract (%)
2011-12	23	28	21
2018-19	26	29	19

Source: Centre for Policy Research (2020)

Minimum Wages: Minimum wages are "the minimum amount of remuneration that an employer is required to pay wage earners for the work performed during a given period, which cannot be reduced by collective agreement or an individual contract." In reducing labour income inequality, minimum wage fixation plays an important role. It also helps align real wages with productivity growth by coordinating macro-level wage increases with inflation and output measures. The need for adequate minimum wages to protect informal workers of the coal economy is important in the absence of collective bargaining within the current context of labour informalisation in the coal economy. By increasing the relative earnings of low-wage workers, minimum wages diminish wage and income inequalities and the gender wage gap.

There is an evident need to codesign with the people of the Coal sector a mechanism and framework for addressing job losses from coal phase-down activities in India, aligned with social security and minimum wage assurance measures, in the backdrop of the Viksit Bharat Goal of 2047 and Net Zero 2070.

Conclusion & Recommended Action Areas

The results of our scenario-building exercise assessing thermal coal demand under a high-income, Net Zero–aligned India by 2070 indicate that coal will remain central to India's energy security in the short and medium term, with dependence likely to persist until at least 2055. Despite the rapid expansion of renewable energy sources (RES), structural constraints related to intermittency, storage limitations, grid integration, and rapidly rising electricity demand will limit the immediate substitution of coal-based thermal generation.

The coal sector functions not merely as an energy provider but as a foundational socio-economic pillar for several Indian states. It supports direct and indirect employment, contributes to state revenues, underpins rail freight earnings, and sustains regional industrial ecosystems. ACPET's macroeconomic modelling shows that reductions in coal-based capacity lead to disproportionate employment losses, while expansion of RES capacity and generation does not automatically offset these impacts without robust welfare transfers and labour transition frameworks. Mechanisation and automation further intensify employment vulnerability, particularly among semi-skilled and informal workers.

The coal phase-down is therefore not solely an environmental or technological challenge but fundamentally a socio-economic transformation. If unmanaged, it could lead to labour displacement, informalisation, fiscal shocks in coal-bearing states, and widening regional inequality. If managed strategically, however, it could create opportunities for economic restructuring, skill upgrading, green industrialisation, and institutional strengthening.

International experience suggests that successful transitions rely on strong social security systems, enforceable minimum wage regimes, active labour market policies, and institutionalised social dialogue. India’s existing legislative architecture, including the Labour Codes and the Unorganised Workers’ Social Security framework, provides an initial foundation, but implementation must be strengthened and tailored to coal-dependent regions.

A balanced, people-centric energy transition strategy must therefore rest on five pillars:

a) Energy realism – recognising coal’s continued role while accelerating RES integration alongside grid and storage readiness.

b) Labour protection – universalising social security, enforcing minimum wages, and providing transition-linked income support.

c) Reskilling and mobility pathways – enabling workers to move into renewable energy, manufacturing, infrastructure, and allied sectors.

d) Fiscal transition planning – preparing coal-producing states for revenue diversification and economic restructuring.

e) Phased and data-driven mine closure planning aligned with economic, environmental, and social considerations.

India’s transition must be gradual, just, and consistent with its growth and development priorities. Coal phase-down cannot precede the readiness of alternative systems across energy, employment, fiscal capacity, and institutions. Achieving Net Zero 2070 while sustaining inclusive growth, therefore, requires a calibrated glide path in which coal’s role declines progressively as renewable systems mature and social safeguards deepen. The central policy challenge lies in synchronising these timelines to ensure that climate ambition strengthens rather than destabilises the foundations of Viksit Bharat 2047.

Action Areas to Actualise Development and Emission Goals

Three likely trends emerge in the various scenarios: An increase in demand for electricity, a tremendous scale-up required in cleaner sources of electricity generation and a continued need for Thermal Power Plants well into 2060-2070. While the projections may vary across models, these trends are perhaps inevitable. Policy planning must therefore begin early to align infrastructure, investment, and institutional capacity with expected growth. The authors suggest the following:

a) Integrated Planning Across Generation, Transmission, and Distribution

Planning frameworks need to take cognisance of gestation periods of asset creation for generation, transmission, and distribution. Coordination between Central and State-level entities, along with public and private sector entities, is critical. The PM Gati Shakti National Master Plan portal can serve as a central coordination mechanism by mapping information on roads, railways, transmission corridors, and future emerging Demand Centres for power, such as industrial corridors, data centres, smart cities, residential and commercial clusters, hospitality hubs, new roads with EV charging points, etc. This will enable power producers and transmission planners to plan investments with assured offtake in sight. States can better synchronise expansion of their distribution networks with demand centres and inter-state transmission lines to avoid bottlenecks, delays and stranded assets. Grid stability planning will also become increasingly important as intermittent RES generation grows alongside stable base-load sources such as coal, nuclear, and large hydro.

b) Long-Term Policy- Certainty for Clean Energy Investments

Long-term policy frameworks and legislative commitments are required to support investments in cleaner electricity sources such as solar, wind, and nuclear power. New and additional investments are expensive. Policy certainty can strengthen market confidence, encourage adoption of cleaner industrial processes such as electric arc furnaces, and support infrastructure development, including EV charging networks, battery storage, and pumped storage facilities.

c) Scaling Renewable Energy Sources with Storage:

Large-scale deployment of renewable energy requires addressing challenges related to technology development, domestic innovation, and supply-chain security. Storage will play a critical role in managing intermittency in solar and wind generation. Planning for pumped storage capacity, developing battery manufacturing capabilities, securing raw materials such as lithium, advancing research on emerging battery technologies, and reducing import dependence will be essential for reliable and cost-effective expansion of renewable power.

d) Planning for micro grids:

Decentralised renewable systems, including smaller solar farms with storage, can support microgrids in remote areas. Dedicated power supply arrangements for emerging demand centres such as data centres should be incorporated into national and state-level planning. Efficient utilisation of surplus power from captive plants can also reduce wastage and improve overall system efficiency.

e) Ensuring Supply Chain for RES with Technological Sovereignty:

Renewable Energy components like Solar cells (polysilicon, wafers, PV cells), Battery Storage (Lithium, Li-Ion battery cells), Magnets, etc., are still import-dependent. Secure supply chains with appropriate indigenized capacity are the need of the hour as we plan and implement Net Zero@2070. Industries should be mandated to do R&D in coordination with colleges across the country (not restricted to a few islands) and a skill pool of the needed scale, with job opportunities planned in India. This would ensure the timely scaling up of RES with storage and cost optimisation.

f) Improving the way we use coal:

Ultra Super Critical and Advanced USC TPPs are more energy efficient. India has several active subcritical plants that have outlived their economic life. With the projected increase in thermal coal demand, new thermal plants are going to be a constant feature of the energy mix in India. These plants need to be designed to minimise coal consumption. Emerging technologies such as coal gasification, carbon capture and storage (CCS), and advanced combustion systems offer pathways to reduce emissions intensity. All these methods could contain emissions while using coal, a domestic resource, more efficiently. Existing evacuation rail networks could be sustained for the transportation of coal gasification products.

g) Re-skilling workforce:

Even as demand for thermal coal will rise towards 2047 and beyond, the focus on the need for addressing the rehabilitation of mining workers and labour in ancillary sectors will not go away. New mines are opening, and old mines are closing. Workers around a closed mine should get better employment opportunities through prompt action on imparting them skills that are aligned with modern industries and flourishing trades- Manufacturing of PV cells, battery cell technology, road and rail construction, jobs in creating and maintaining transmission and distribution networks, maintenance of solar and wind farms, coal gasification projects and so on. This will lend heft to existing rehabilitation packages for mining communities and make for a just energy transition.

Way Forward for Future Research

Given the critical role of electricity in sustaining steady economic growth in India, ensuring adequate and reliable power supply will require a balanced and realistic approach to coal phase-down. A careful assessment is needed of the time required for renewable energy sources such as solar, wind, and nuclear to progressively assume the role currently played by thermal power plants, while meeting rapidly rising electricity demand. At the same time, expansion of electricity supply must ensure that industrial growth and emerging demand centres, such as data centres, do not crowd out access for domestic consumers.

ACPET recognises that deeper analytical work is required beyond the framework developed in the present study. Key areas for further research include:

a) Dynamic energy demand modelling: Developing a dynamic energy demand model that translates energy demand into coal demand while incorporating emerging structural drivers such as rapid EV adoption, expansion of data centres, increasing use of AI in energy systems, industrial corridor development, and the evolving sectoral composition of GDP across manufacturing and services.

b) Comprehensive assessment of domestic coal supply: Profiling the full spectrum of potential domestic coal supply in terms of coal quality, extraction costs, evacuation logistics, and transportation infrastructure. Such analysis can support the development of a prioritised framework for mine closure. This should also include assessment of effective coal costs for thermal power plants based on coal linkages, as well as the role coal gasification could play as a bridge pathway toward Viksit Bharat 2047 and Net Zero 2070.

c) Plant-level analysis of thermal power capacity: While the present study undertakes a preliminary assessment of the thermal power plant (TPP) landscape, further work should deepen this supply-side analysis through plant-level profiling of age, efficiency, coal linkages, utilisation patterns, and potential retirement pathways.

d) Assessment of non-thermal coal demand: A comprehensive evaluation of coal demand beyond power generation, including sectors such as cement, sponge iron, captive power, and other industrial uses. Understanding trends in non-thermal coal consumption is essential for developing a holistic perspective on the future of India's coal economy.

e) Grid implications of rising renewable energy share: Detailed analysis of the interaction between renewable energy expansion and coal demand, including its implications for thermal power plant utilisation and grid stability. Since solar and wind capacity are geographically concentrated in a few states, increasing reliance on interstate power imports may raise issues related to transmission costs, reliability, and grid management that must be addressed to avoid disruptions to economic activity.

f) Impact of efficiency improvements on coal demand: Assessing how improvements in operational, process, and energy efficiency across the power sector and broader economy could influence coal demand. Scenario analysis should incorporate technologies such as advanced ultra-supercritical (A-USC) power plants and efficiency-enhancing innovations across manufacturing and services, which could enable more efficient use of coal while maintaining emission reduction trajectories.

g) Socio-economic implications of coal demand reduction: Evaluating the economic impact of declining coal demand on the national economy and on coal-producing states in particular. This includes analysing implications for public revenues (including railway freight), employment, and household incomes among workers directly and indirectly dependent on coal. Identifying mitigation strategies and policy templates for timely intervention will be critical for minimising adverse socio-economic effects.

h) Financing and capacity expansion for non-fossil power: The large-scale expansion of non-fossil power sources, including solar, wind, and nuclear, along with battery storage and transmission infrastructure, will require substantial financing and accelerated investment. Future research should assess the potential scale of capacity creation under different scenarios, including technological readiness, domestic manufacturing capability, import dependence, investment requirements, and project gestation periods. Such analysis can help establish realistic transition timelines for expanding clean energy while planning coal phase-down in alignment with India's growth objectives and Net Zero 2070 commitments.

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Annexure

Factor for Coal Demand and Steam Capacity

The share of generation from steam-based power plants is juxtaposed with the total gross generation to estimate the contribution of coal-based thermal power plants (TPPs) to electricity generation. Using this share, the coal requirement is calculated by applying a generation-to-coal ratio based on 2024 values. This ratio is assumed to remain constant over the analysis period, under the assumption that the plant load factor (PLF) of coal-based TPPs will not change significantly over the next two decades. To estimate the capacity required for a given level of generation, a generation-to-capacity factor is derived by taking the ratio of installed capacity to actual generation for coal-based TPPs in 2024. This ratio is also assumed to remain constant over the analysis period, from 2022 to 2047.

Table A.1 Conversion factor for thermal coal demand and steam capacity requirement

Factor	Value	Unit
Coal Demand Factor	0.603	Tonnes per GWh
Factor for Steam Capacity	0.189903701	GW per BU

$$\text{Coal Demand Factor} = \frac{Coal\ despatch\ (Utilities+non\ utilities)MT}{Total\ generation((utilities+non\ utilities)GWh} = \frac{785.396\ MT+36.323MT}{1361.92\ BU} = 0.603\ \text{MT/BU}$$

$$\text{Factor for Steam Capacity} = \frac{Total\ Installed\ capacity(utilities+non\ utilities)\ GW}{total\ genetraion\ (utilities+non\ utilities)GWh} = \frac{258.63\ GW}{1361.92\ BU} = 0.189903701\ \text{GW/BU}$$

RES generation -to-capacity factor

Total electricity generation is further disaggregated by the share of different sources, namely, steam (coal-based), renewable energy (RE), and others. In this analysis, the RE category includes solar, wind, small hydro, and bio-power. For the year 2024, the source-wise share in RE generation is taken as: solar - 50%, wind - 35%, bio-power - 9%, and small hydro - 5%. Using these shares, source-specific electricity generation is estimated. Once the generation from each RE source is determined, it is converted into the required installed capacity using a generation-to-capacity conversion factor (inverse of CUF). Unlike coal-based plants, where this factor is assumed constant, in the case of RE sources, the conversion factor is assumed to improve over time, reflecting expected technological advancements and better capacity utilisation (CUF) for each source over the analysis period.

CUF (%) =

(Installed Capacity (MW)×Total Hours in the PeriodActual Electricity Generated in a Period (MWh))

×100

Capacity (GW/BU) = 1000 ÷ (CUF×8760)

Regression Specification

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

where:

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

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