November 2025

Institute for Energy Economics and Financial Analysis

Jharkhand's Just Transition: A Roadmap for Economic Growth and Diversification

Mobilising Capital, Protecting Communities and Building a Low-carbon Future

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Message

Jharkhand stands at a pivotal juncture as the journey toward the sustainable just transition is both a challenge and a high-return opportunity. It also offers a unique moment to redefine the growth trajectory — one that enhances energy security, restructures industrial and business operations, and ensures long-term socio-economic resilience.

The upcoming decades will determine how effectively the state builds resilient institutions, diversifies its industries and businesses, and ensures climate-compatible growth for a future-ready economy.

To undertake the transition journey, robust financial planning is a necessity as it can provide a guiding framework to balance growth with a sustainable and inclusive approach, enabling the state to achieve long-term prosperity by focusing onkey development priorities.

It gives me immense pleasure that a report has been prepared by the Task Force-Sustainable Just Transition, which aims to fill this void by analysing the financing needs of the just transition and providing a pathway for fiscal planning. The state needs a coherent financing architecture, evidence-driven planning, and adaptive governance systems that can respond to emerging risks and opportunities.

Jharkhand has the opportunity to demonstrate how forward-looking governance, policy coherence, and stakeholder empowerment together can shape a model of green growth for a sustainable future.

24/10/25

(Ajoy Kumar Singh)

Message

Shri Prashant Kumar, I.A.S.
Secretary, Department of Finance
Government of Jharkhand

Transitioning to a greener economy requires more than policy ambition—it requires sustained financial innovation and an enabling atmosphere for diversified investment. Climate finance plays a transformative role in bridging these aspirations, ensuring that the most vulnerable regions and prioritised sectors have adequate resources and resilience to adapt and thrive.

Financial Planning for a sustainable just transition requires a strategic direction—anchored in transparent systems, evidence-based decision-making, and people-centric implementation. To navigate this transformation, robust governance systems and institutional mechanisms need to be strengthened to steer planning, coordination, and monitoring.

The Task Force–Sustainable Just Transition, in association with the Institute for Energy Economics and Financial Analysis (IEEFA) and the Centre for Environment and Energy Development (CEED), has undertaken a commendable effort in preparing a report that outlines the overall financing needs of the just transition and proposes financial mechanisms and planning pathways for the state. The report's insights and action points will serve as critical inputs for resource optimisation and policy directions.

With climate imperatives driving structural shifts in economies, Jharkhand's initiative illustrates how fiscal governance and coherent frameworks can convert climate risks into engines of socio-economic transformation.

Message

Shri A.K. Rastogi, I.F.S. (Retd.)
Chairperson, Task Force-Sustainable Just Transition
Government of Jharkhand

As Jharkhand envisions becoming a future-ready economy with the ambition towards net-zero, the challenge lies not in managing the fossil fuel-dependent ecosystem, but in developing the new, resilient, and green ones. A well-planned, sustainable just transition strategy can transform potential disruption into opportunity — enabling the state to capture high-growth sectors, create sustainable livelihoods, and strengthen local economies.

Without proactive planning, it could trigger fiscal strain and social distress. Through strategic diversification, Jharkhand can mitigate the impacts of the transition by expanding its clean energy, manufacturing, and service-based sectors. This will strengthen the new economic opportunities further. To realise this, exploring new avenues of finance and investment and leveraging national and global opportunities will be central to this effort.

This pathbreaking report undertakes a just transition cost modelling exercise to quantify transition finance needs with a decadal-based analysis from 2026 to 2070. It also provides a financing framework that outlines its various components, such as assessment of assets, identifying types and sources of finances, outlining risk mitigating instruments and revenue substitution. Further, the financing pathways indicate a just transition fund, utilising DMFT and CSR to provide support for a range of work, e.g. economic diversification, cleaner energy ecosystem, industrial decarbonisation, labour reskilling, land repurposing, and social-physical infrastructure.

Jharkhand has taken formidable steps towards meeting climate and development goals. The transition planning calls for a multi-pronged approach that integrates fiscal planning, policy innovation, and people-centric governance — ensuring that it takes a comprehensive approach to build a climate-resilient, forward-looking economy.

Contents

Figures and tables

Key findings

The report estimates that US$256 billion will be needed between 2026 and 2070 for Jharkhand's transition from fossil fuels, covering coal mining and thermal power, decarbonizing the steel sector, providing social support, and driving economic diversification into low carbon sectors to maintain both social stability and economic growth.

Coal and petroleum contribute 32% to the state's own revenue, exposing Jharkhand to major fiscal risks as fossil fuel use declines.

Over US$12.5 billion will be needed to reskill, compensate and support livelihoods and communities dependent on the fossil fuel economy.

Public funds alone are not sufficient to finance the transition. A sustainable finance framework involving public finance, private investment, concessional debt and international climate funds is essential.

Executive summary

The global commitment to climate goals necessitates an almost complete shift from a fossil fuel-based economy to a low-carbon one. Aligning with this global effort, India aims to reduce its emission intensity by 45% by 2030 from 2005 levels and achieve net-zero emissions by 2070.[1] This shift entails phasing out carbon-intensive assets, building new low-carbon capacity, and mobilising unprecedented levels of capital. For Jharkhand, a state deeply dependent on the fossil fuel economy, this transition is both a high-risk challenge and a high-return opportunity with the potential to enhance energy security, create large-scale employment, and drive long-term sustainable growth.

Fossil fuels contribute 32% to Jharkhand's own revenue, with coal alone accounting for 17%.[2] More than half of the State Goods and Services Tax (SGST) collection comes from fossil fuel-dependent industries. Any decline in coal production or consumption will directly impact the state's revenue streams, constraining its ability to fund education, healthcare, welfare programmes and other essential social services. The economic repercussions would extend beyond public finances, affecting employment, supply chains and local business ecosystems. Additionally, given that a substantial share of the budget is committed to fixed obligations such as administrative costs and debt servicing, any revenue shortfall would further erode fiscal flexibility, disproportionately burdening vulnerable communities.

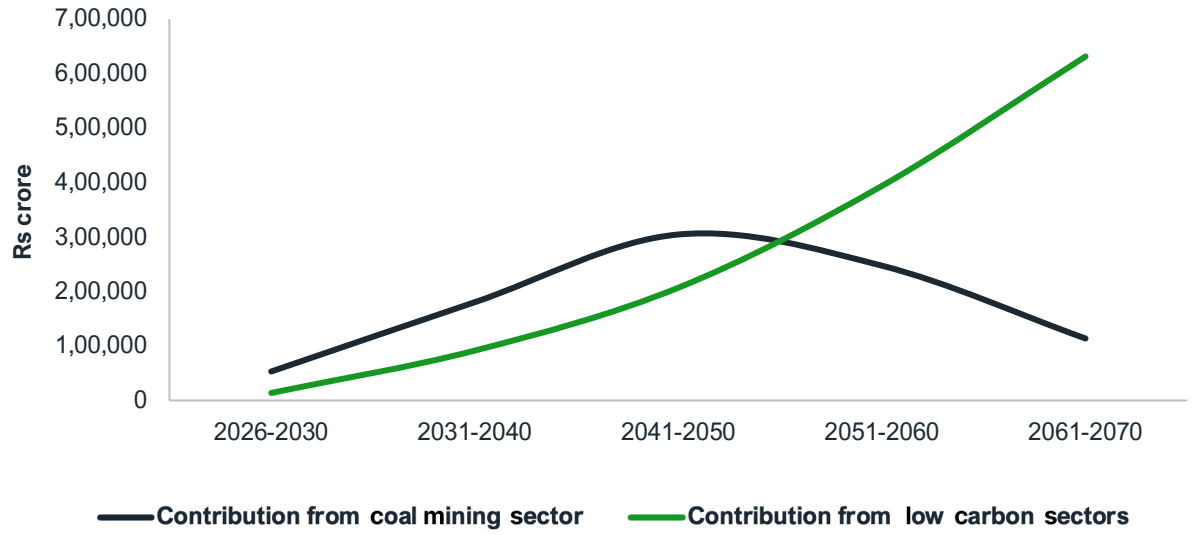
Jharkhand lags the national average in green transition metrics. Renewable energy, for instance, accounts for less than 12% of its installed capacity compared with the national average of almost 50%.[3,4] This underperformance, however, masks considerable opportunities across multiple low-carbon domains. The state possesses renewable energy resources, including abundant solar irradiation, and substantial biomass availability. It has an industrial base suitable for manufacturing low-carbon technologies, a concentration of critical mineral reserves essential for clean energy, and a strong steel sector capable of serving as an anchor for green hydrogen demand.

However, realising this potential will require far more than sectoral investments. The state must begin transition planning as a priority. Building the institutional frameworks, governance systems, regulatory clarity and human capital necessary to manage such a complex transformation takes years, if not decades. Early planning will allow the state to capture first-mover advantages, attract large-scale investment, and build the institutional and human capital needed to drive a just, inclusive and sustainable transition.

Our analysis and projections show that a concerted effort to grow the low carbon sectors within the state on priority will more than offset revenue losses from coal assets over the coming decades.

[1] Press Information Bureau (PIB). India to cut its carbon emissions. 18 December 2023.
[2] IEEFA. . September 2024. Page 8.
[3] India Climate and Energy Dashboard (ICED), National Institution for Transforming India (NITI)ICED Niti Aayog.: Jharkhand installed capacity. August 2025.
[4] Central Electricity Authority (CEA). All India installed capacity (in mw) of power stations. 30 June 2025. Page 1.

Figure 1: Impact of low carbon sectors growth on state budget revenues (Rs crore)



Source: IEEFA analysis

As illustrated in Figure 1, revenues from state goods and services tax (SGST), driven by economic diversification into low-carbon industries, are expected to surpass coal mining royalties after 2047, when coal revenues peak before declining through 2070. Over the full transition period (2026-2070), this substitution delivers a net positive impact of about Rs 6.7 trillion (US$79.3 billion) to the state budget. Importantly, these estimates only accounts for the state's own revenues (royalties and SGST) and do not include other budgetary revenue streams, including transfers from the central government.

This report sets out a detailed, actionable roadmap for Jharkhand's Just Transition. It quantifies the costs of coalmine and thermal power plant closures and remediation, and of steel sector decarbonisation, with these sectors being prioritised for their size, economic importance, and Just Transition implications. It then models decadal transition expenditures, identifies high-potential diversification sectors, and proposes an integrated sustainable finance framework designed to mobilise private capital while ensuring an equitable transition for all stakeholders.

The report focuses specifically on diversifying Jharkhand's economy by leveraging low-carbon opportunities aligned with the state's comparative advantages and ensuring a Just Transition. It does not model the impact of fossil fuel expansion or subsequent diversification on the state's greenhouse gas (GHG) inventory. However, given the dominance of the energy sector—particularly industrial energy use and electricity generation—in Jharkhand's GHG profile[5], and the projected growth of thermal power and the iron and steel industries in the state, transitions within these sectors will play

[5] GHG Platform India. Trend Analysis of GHG Emissions of Jharkhand. September 2022

a decisive role in significantly reducing the state's emissions over the coming decades. Consequently, the cost of transition estimated in the report is only for the specific fossil fuel and economic diversification sectors considered.

Lastly, all assumptions related to expansion of current fossil fuel capacities, technological interventions for decarbonisation, and economic diversification is based on current available data, and economic & technological feasibility. The report is intended to showcase one feasible scenario for Jharkhand's Just Transition, however there may be other scenarios too that may emerge going forward.

Cost of transition

This report, developed by IEEFA as part of the Jharkhand government's Task Force-Sustainable Just Transition, estimates the state will require nearly US$256 billion (Rs22 trillion)[6],[7] from 2026 to 2070 to transition from fossil fuels without disrupting the social infrastructure.[8] This estimate includes the costs of closing and remediating coalmines and thermal power plants, decarbonising steel sector, supporting workers and communities, and investing in new low-carbon industries.

Table 1 provides a breakdown of the estimated decadal cost of transition for Jharkhand across different assets and activities.

Table 1: Decadal cost of Just Transition for Jharkhand (US$ million)

Just Transition decadal cost	2026-2030	2031-2040	2041-2050	2051-2060	2061-2070
Coal mine reclamation	1,270	1,297	1,218	7,099	7,257
Thermal power plant decommissioning	3	214	321	694	4,431
Labour support	140	196	270	1,066	7,435
Community resilience	-	-	6	1,111	2,312
Economic diversification	4,800	23,931	25,877	53,429	97,764
Steel Sector decarbonization	958	1,079	5,343	5,222	-
Critical minerals	400	182	185	182	148
Total Just Transition Cost	**7,571**	**26,899**	**33,220**	**68,803**	**1,19,347**

Source: IEEFA

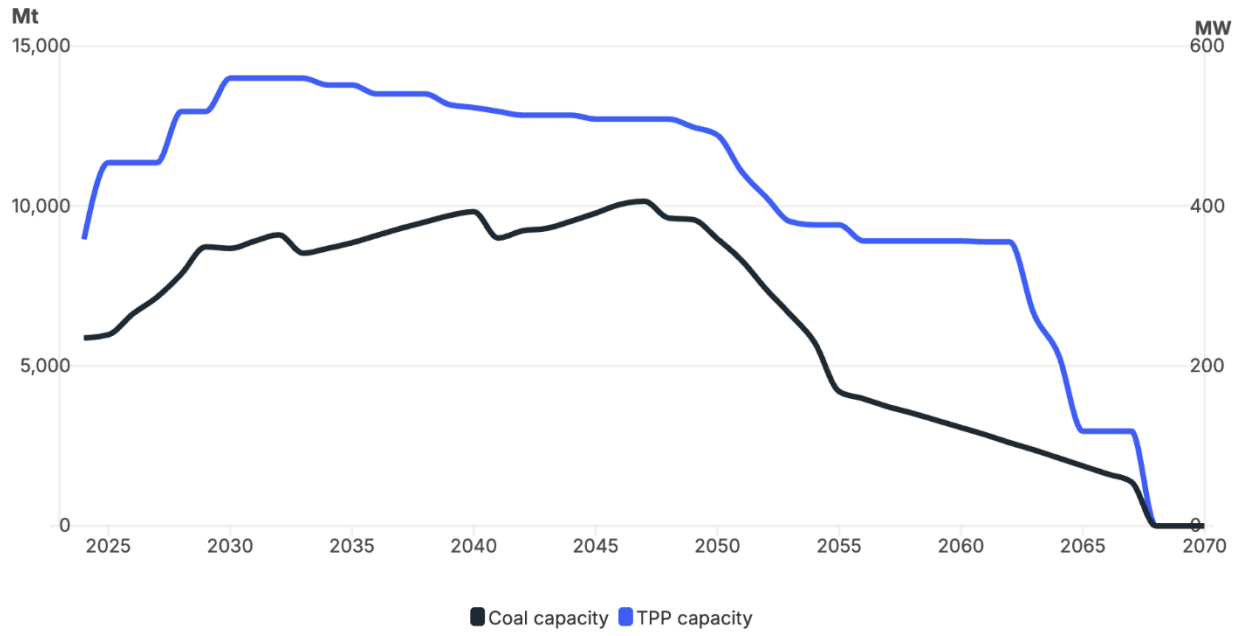
Coal remains at the heart of Jharkhand's fiscal and industrial structure. The state has 217 coalmines of which 101 are active, with a combined capacity of 259 million tonnes per annum (Mtpa). IEEFA forecasts that coal production in Jharkhand will peak in 2047, after which there will be retirements

[6] Forex conversion: forex conversion to USD has been done based average USD rates of the past 12 months as of 30th June 2025.
[7] The report considers coal mining, thermal power generation, and steel as key sectors for fossil fuel transition. Economic diversification sectors have been shortlisted based on the state's comparative advantage. The overall cost of transition will be higher considering other sectors of the state's economy.
[8] Not adjusted for inflation.

through to 2070. The assumptions assume that majority of coal mines will be operated for entirety of their scheduled life, and only a few mines for which the useful life runs beyond 2070 will be closed on an accelerated basis. The total net cost of coalmine closures is estimated at US$18.1 billion (Rs 1,526 billion)—after deducting the escrow funds held for mine closures)—covering technical closure, biological reclamation, post-closure monitoring and early-closure compensation. Notably, the regulatory escrow balances are insufficient, with actual technical closure costs projected to be nearly 3 times higher than legacy norms.

Thermal power plants (TPPs) are also a major part of the landscape. As of 2024, Jharkhand operated 34 plants with a combined capacity of 8,955 megawatts (MW). IEEFA projects that TPP capacity will peak in 2030, stabilise until 2040 and decline thereafter. The cost of retiring TPPs between 2030 and 2070 is estimated at US$5.7billion (Rs 476 billion) (after offsetting any recovery through scrap sale), including decommissioning, ash pond closure, site remediation and early-closure compensation. Unlike mines, there are no escrow requirements or regulatory guidelines for TPP decommissioning, raising the risk of inadequate closures without clear standards and financing mechanisms.

Figure 2: Projected trajectory of coalmine and thermal power plant closures in Jharkhand



Sources: Ministry of Coal, Jharkhand Department of Mines and Minerals, Central Electricity Authority, Global Energy Monitor, IEEFA

Labour and community support costs will be significant. Reskilling, upskilling and compensation packages for both formal and informal workers, as well as for those indirectly dependent on coal are estimated to cost US$9.1 billion (Rs766 billion) between 2030 and 2070. Additionally, sustaining community infrastructure and services that rely on coal industry funding will require about US$3.4 billion (Rs288 billion).

To manage the economic and fiscal risks of phasing down coal while unlocking growth opportunities, this report identifies five priority sectors for economic diversification (see Box 1). These sectors align with Jharkhand's resource base and industrial capabilities, and India's broader energy transition trajectory. We have identified the areas based on stakeholder consultations and secondary literature review.

Box 1: Key areas for economic diversification

1. **Low-carbon power generation:** Jharkhand has a proven potential of 50 gigawatts (GW) of renewable energy across different assets, likely increasing as coal assets retire and land becomes available. As state-owned thermal power plants phase out, renewable energy and storage have the potential to meet Jharkhand's power demand. Developing these assets will require more than US$57.2 billion (Rs4.8 trillion) in investment, alongside strategic transmission and distribution upgrades. Siting renewable and storage projects in districts affected by coalmine closures could help repurpose land, stabilise local economies, and provide alternative employment.

2. **Energy storage:** Pumped hydro storage (PHS) with a potential of 20 GWh is also significant in Jharkhand and should be prioritised by the government as a core part of the state's transition strategy. The resource offers the state a significant opportunity to position itself as a leader in firm, round-the-clock renewable power. Its PHS capacity can benefit from multiple tailwinds, including new forms of renewable energy bids that mandate storage components, and the growing corporate power purchase agreement (PPA) market. Importantly, Jharkhand's current power demand is relatively low, which means that even after meeting the state's own needs, a significant surplus of PHS capacity could be exported to other states, positioning the state as a key supplier of firm clean power to the national grid.

   In parallel, battery energy storage systems (BESS) should be promoted to complement PSP by offering short-duration, flexible storage solutions close to demand centres. Developing storage assets in districts affected by mine closures can also generate local employment, repurpose land and strengthen Jharkhand's role in India's clean energy transition.

3. **Green hydrogen production:** Green hydrogen production in Jharkhand is projected based on its sizeable iron and steel manufacturing capacity, and the large fleet of heavy goods vehicles (HGVs) serving the coal mining sector. It is assumed that from 2035 onwards diesel HGVs in coal mining will shift progressively to hydrogen fuel cell vehicles, with the transition continuing through 2065. While the demand considered here is limited to coal mining trucks, the potential becomes significantly larger once other mining sectors and long-haul freight transport are factored in.

For the steel sector, a co-located hydrogen hub model is proposed to minimise transport costs and ensure stable offtake, while for heavy-duty trucking, a hub-and-spoke model with a dedicated distribution network is envisaged. Integrated steel producers can act as anchor consumers, leveraging Jharkhand's iron ore availability and industrial base to also attract new low-carbon steel units. The overall capital expenditure of setting up green hydrogen plants is estimated to exceed US$4.2 billion (Rs 356 billion) by 2050, assuming a decline in cost of electrolysis and renewable energy supply.

4. **Energy plantations and natural farming:** Energy plantations and natural farming can diversify Jharkhand's agriculture economy towards low-carbon, higher-value activities. The state's significant non-forest wasteland could be partly converted to bamboo plantations[1] by 2070, supplying biomass for pellets used in co-firing, and biochar. In parallel, natural farming can be scaled across rainfed cropland, reducing input costs, improving soil health, and enabling carbon revenues. Together, these models position Jharkhand as a hub for clean energy feedstock, and bio-based products. Additionally, opportunities such as biochar hubs and ethanol blending feedstock can also be explored to expand economic and environmental benefits.

5. **Mining critical minerals:** Jharkhand can leverage its mining expertise to become a leader in critical mineral production essential to energy transition. The state already has identified reserves of copper, graphite, nickel, cobalt, quartz and, potentially, lithium. Investment of about US$1.1 billion (Rs92 billion) could catalyse domestic supply chains for solar, wind, battery and EV manufacturing. With government incentives for exploration, and streamlined auctions, the state is well-placed to pioneer integrated mining and refining hubs. This would enable value addition, strengthen India's clean energy supply chains, and position Jharkhand as a national leader in critical minerals.

6. **Manufacturing low-carbon technologies:** Finally, Jharkhand's rich reserves of critical minerals offer an opportunity to establish manufacturing units, such as solar photovoltaic (PV), battery energy storage systems (BESS) and electric vehicle (EV) production facilities. With cumulative investment needs exceeding US$138 billion (Rs 11.6 trillion), the state can leverage national momentum on manufacturing and the low-carbon transition to attract large-scale industrial projects. By moving beyond raw mineral extraction to local processing and end-use manufacturing, Jharkhand can capture greater economic value, generate higher-skilled employment, and position itself as a hub for low-carbon industrial growth.

IEEFA also estimates that by transitioning away from fossil fuel-dominated sectors into new low-carbon ones, the state will be able to more than offset the loss of revenues it generates from the fossil fuel economy. Further, our projections estimate that based on this projected growth, the state exchequer will be able to generate additional revenue in the form of taxes and royalties of US$79.3 billion (excluding central transfers and targeted grants) between 2026 and 2070, far exceeding the loss of revenues from coal mining sector.

Financing the transition

Financing this transformation will require a co-ordinated strategy that blends public, private and multilateral capital. Public finance will be essential to fund social support measures, for early retirement of carbon-intensive assets, and enabling infrastructure. Private capital will need to flow into commercial sectors such as renewable power, manufacturing and hydrogen.

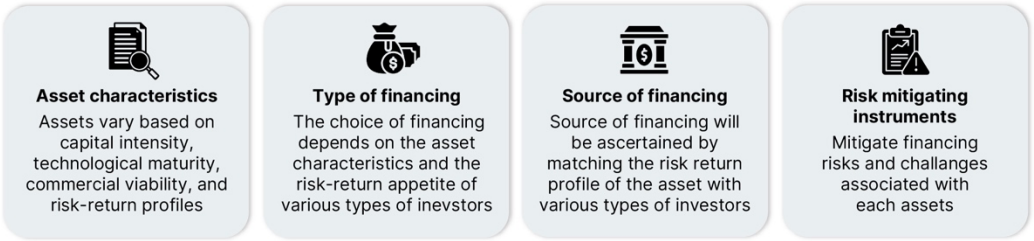
For coal asset retirement, this report proposes a state-aligned 'coal asset retirement facility' anchored by multilateral development banks (MDBs), blending grants with long-tenor, low-cost debt. This facility would finance technical closure, environmental remediation and early-closure compensation, while ensuring site repurposing for productive use. State-level financing facilities have already been set up across India such as the Tamil Nadu Investment Fund Management Corporation (TNIFMC)[9], which manages an alternate investment fund (AIF) structure based Green Climate Fund. Another example is Kerala Infrastructure Investment Fund Board (KIIFB) bond financed vehicle, along with Kerala Startup Mission (KSUM) Fund-of-Funds (FoF) limited partner model.[10] The SEBI-registered Maharashtra Innovation & Technological Development Fund (MITDF)[11] and the Odisha Startup Growth Fund[12] (SIDBI-managed FoF) are other examples. These templates illustrate multiple governance and capital-stack options and fund structures that Jharkhand can adapt for the coal asset retirement facility.

Renewable power, storage and manufacturing projects will require patient equity, concessional debt, credit enhancement and guarantees, and payment security mechanisms. Green hydrogen projects, while not yet economically viable, will depend on concessional finance and anchor offtake arrangements to become bankable. Agroforestry and community resilience initiatives will require dedicated blended finance facilities, combining public funds with private investment and carbon market revenues.

This report's sustainable finance framework provides a blueprint that outlines key characteristics, financing types and sources, and necessary risk mitigation for all these identified assets. This framework identifies suitable financing instruments, sources of capital and risk-mitigating instruments to accelerate capital mobilisation for low-carbon technologies. Besides, the framework offers a suitable pathway to finance social welfare and early retirement carbon-intensive assets funded largely by public finances.

[9] TNIFMC. Green Climate Fund.
[10] StartupMission. Fund of Funds.
[11] IDBI Capital. Maharashtra Innovation & Technological Development Fund.
[12] OSGF. Odisha Startup Growth Fund.

Figure 3: The sustainable finance framework



Source: IEEFA

We apply this framework across different economic diversification assets in the state (Table 2).

Table 2: Summary of the application of the sustainable finance framework

	Low-carbon power generation and storage assets					Manufacturing of low carbon assets			Green hydrogen	Sustainable land us	Critical minerals	Steel
	RE (utility scale)	DRE (solar)	BESS	Pumped storage	Bio-mass	Solar PV	BESS	Electric vehicle	GH_2 production	Energy plantation and natural farming	Critical minerals	Steel decarb.
Asset characteristics												
Capital intensive	■	■	■	■	■	■	■	■	■		■	■
Long gestation period	■		■	■	■	■	■	■	■	■	■	■
Medium gestation period		■										
Low to moderate tech./general risk	■	■	■	■		■	■	■	■	■	■	■
High Tech Risk												
Utility style	■											
Revenue uncertainty	■			■	■							
Low opex				■	■							
Low margin/loss making	■		■			■	■		■			
Moderate margin								■				
Type of financing												
Commercial loan			■		■			■				
Bonds	■							■				■
Public equity	■							■				
Proprietary equity	■	■	■	■	■	■	■	■		■	■	■
Risky equity			■			■	■				■	
Grant		■	■	■	■	■	■	■	■	■	■	
Concessional debt		■	■	■	■	■	■		■	■	■	■
InVIT/ securitization/IDF	■											

Sources of financing												
Banks/NBFCs												
Institutional investors												
DFIs/MDBs												
Govt.												
Public sector financial institutions												
Corporations												
Farmers/ communities												
PEs/VCs												
Risk mitigation instruments												
Credit guarantee												
Payment security mechanism												
Insurance												

*Source: IEEFA. *Notes: InvIT = infrastructure investment trust; IDF = India Development Foundation; DFIs = development financial institutions.*

This report also recommends establishing a state-level transition finance platform to co-ordinate pipeline development, standardise documentation, and aggregate risk mitigation tools. A single-window "green cell" could streamline land allocation, approvals and investor facilitation, supported by regular investment summits with MDBs, development financial institutions (DFIs) and private investors.

Jharkhand stands at an important crossroads in India's ensuing energy transition. A well-calibrated strategy for a Just Transition today will help the state not just diversify but also grow its economy multifold in the coming decades.

1. Introduction

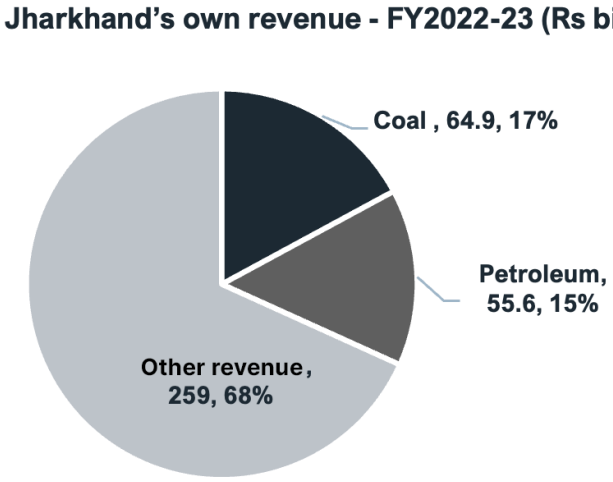
India voluntarily declared it would reduce the emissions intensity of its gross domestic product (GDP) by 45% from 2005 levels by 2030 and achieve net-zero emissions by 2070.[13] Achieving the net zero goal needs an unprecedented transition in the real economy—retiring carbon-emitting assets and creating carbon-mitigating assets. This requires large-scale capital investment in a range of low-carbon technologies, including renewable energy, clean transportation and green hydrogen.

This transition is even more challenging for economies reliant on fossil fuels. Yet, it offers a vital investment opportunity in rapidly growing low-carbon sectors, and growth momentum will continue for several decades. A fossil-fuel-importing country such as India can reduce its import bill significantly, stabilising the currency and bolstering its energy security. Furthermore, these sectors can generate substantial employment opportunities.

1.2 Green transition: Implications for Jharkhand

Jharkhand's reliance on coal and petroleum is profound. In the fiscal year (FY) 2023, fossil fuels contributed 32% to the state's own revenue and 15% of its total revenue.[14] Coal alone accounted for 17% of the state's independent income, with petroleum contributing an additional 15%.

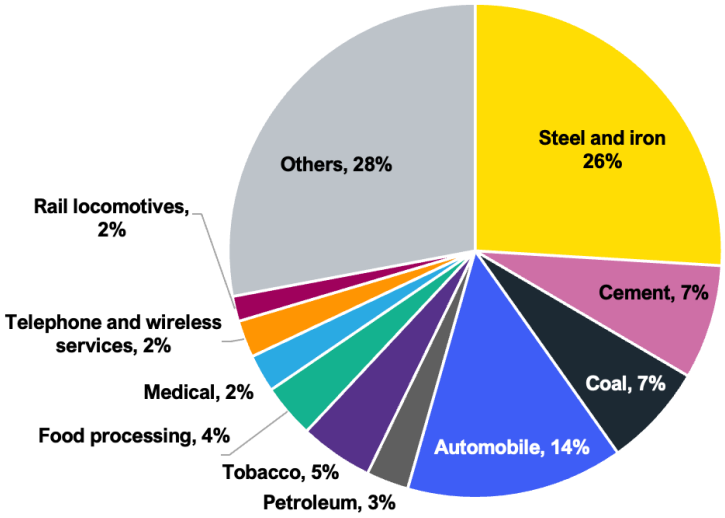
Figure 4: Jharkhand's direct fossil fuel revenue dependency



Source: IEEFA

[13] PIB. India stands committed to reducing emissions Intensity of its GDP by 45 percent by 2030. 22 December 2022.
[14] IEEFA. Just transitioning financing pathway. September 2024. Page 8.

Figure 5: Jharkhand's SGST collection (FY2022-23)



Source: IEEFA

Analysis of the state's GST database underscores this dependency, as 57% of Jharkhand's GST collection comes from fossil fuel-dependent industries such as steel, iron, cement, and petroleum. The mining and quarrying sector, dominated by coal, contributed about 8% of the gross state value added (GSVA) in FY2022-23. The manufacturing sector, heavily reliant on coal, accounted for 23.2% of GSVA. These industries not only dominate Jharkhand's industrial profile but also influence the state's transport and electricity sectors.

While India is increasing coal production to meet its energy demand, the long-term outlook for the fuel is uncertain due to the rise of renewable energy as an alternative low-cost and low-carbon energy source. Any reduction in coal production or consumption will directly impact Jharkhand's revenue streams and have cascading effects on the economy.

Social sector spending relies heavily on fossil fuel revenues, a critical area of concern. This spending includes vital sectors, such as education, healthcare and welfare programmes. With a large proportion of the state budget allocated to relatively fixed costs, such as administrative expenses and debt servicing, any decline in fossil fuel revenue could significantly constrain Jharkhand's ability to fund social services, disproportionately affecting vulnerable populations.

Additionally, the closure and repurposing of TPPs poses significant challenges for communities relying on coal-related employment. Transitioning to alternative industries requires extensive planning to minimise socio-economic disruptions.

1.3 Status of the green transition in Jharkhand

Jharkhand lags other states in the green energy transition. Renewable energy accounts for less than 12%, or 400MW, of its total installed power capacity of 3GW, compared with the national average of almost 50%.[15,16] The state's renewable energy capacity is roughly divided between hydropower (191MW) and other renewable sources, including solar.[17] Jharkhand's EV sales are also comparatively low. The overall EV penetration rate in the state is 4.6%[18] compared with 7.8% across India[19]. Most EV manufacturers in the country have no meaningful presence in Jharkhand.

The state is advancing its green transition by promoting renewable energy and encouraging private sector involvement through various policies and regulatory measures. The Jharkhand Electric Vehicle Policy 2022 promotes EV adoption with subsidies and incentives, while the 2021 Industrial and Investment Promotion Policy incentivises investment in renewable sectors such as solar, wind and biomass.[20,21] The Jharkhand Solar Policy 2022 targets a 4 GW solar capacity, incorporating distributed and rooftop solar projects, supported by fast approvals and developer incentives.[22]

1.5 Assessing viable timeline for Jharkhand's energy transition

Several states in India have already set net zero targets. For example, Kerala has announced a net zero target for 2050[23], while Maharashtra has set a 2050 target for 43 of its cities.[24] These targets are more ambitious than India's official national net zero goal of 2070. However, state-level targets need to be grounded in their respective socio-economic contexts, sectoral dependencies, and fiscal capacities.

As part of our analysis, we have analysed Jharkhand's transition across two scenarios: 2050 and 2070. The coal capacity in India is expected to peak in 2047 as per Ministry of Coal projections[25]. For Jharkhand, one of India's largest coal-bearing states, adopting a 2050 timeline would imply shutting down all coal mines and coal-based thermal power plants within just a three-to-five-year window (2047-2050). Such an accelerated phaseout is neither socio-economically nor fiscally viable for the state, as it would create a severe shock to employment, state own revenues (over one-third of which come from fossil fuels), and local economies without sufficient time to diversify.

By contrast, a 2070-aligned transition provides Jharkhand with three critical advantages. It allows for gradual asset retirement, enabling the phased closure of coal mines and thermal power plants while

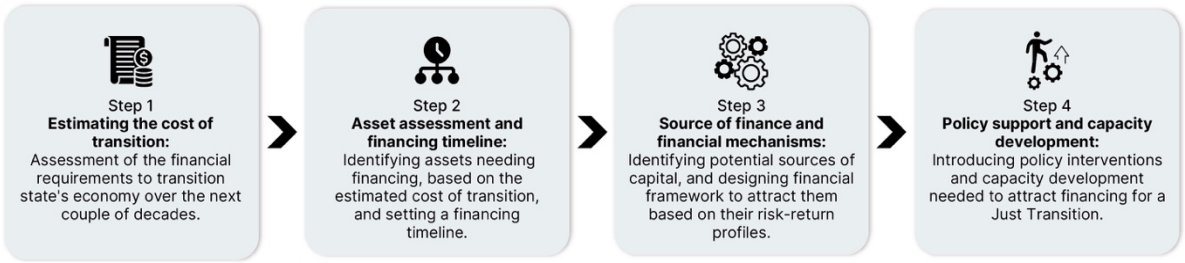
[15] ICED NITI Aayog. Jharkhand installed capacity. August 2025.
[16] CEA. All India installed capacity (in mw) of power stations. 30 June 2025. Page 4.
[17] ICED NITI Aayog. Electricity generation capacity. August 2025.
[18] JMK Research and Analytics. EVs annual report card. April 2025.
[19] Economic Times. EV penetration in India. April 2025.
[20] Clean Mobility. Jharkhand EV Policy. 2022.
[21] ICED NITI Aayog. Jharkhand industrial and investment promotion plan. 2021.
[22] Jharkhand Department of Energy. Jharkhand State Solar Policy. 5 July 2022. Page 1
[23] NKP.Kerela. Net Zero Carbon Keralam through People Campaign. November 2023
[24] The Climate Group. Inside Maharashtra's climate initiatives. April 2025
[25] Ministry of Coal. Growth projection of coal. 26 February 2024.

creating time to repurpose land and redeploy labour. It also provides the necessary time for economic diversification, giving space for renewable energy, storage, green hydrogen, energy plantations, and critical minerals industries to scale up as alternative growth engines for the state's economy. Finally, it ensures financial feasibility, allowing Jharkhand to mobilise concessional finance, blended structures, and state-level facilities in a more sustainable manner to manage the high costs of transition without creating disruptive shocks to its fiscal system and communities.

1.4 Creating an integrated financing strategy for Jharkhand

Transitioning to a greener economy requires careful planning and strategy. A critical cog is attracting massive private sector investment in various low-carbon industries. IEEFA estimates the need for US$256 billion (Rs21.5 trillion) over the next four decades. This estimate reflects transition costs in coal, thermal power, and steel, alongside diversification into certain low-carbon sectors in which Jharkhand has a competitive advantage. In addition, supporting people and communities for an equitable transition will require significant public funding. The state's budgetary resources are insufficient to meet these requirements, necessitating the mobilisation of private capital, and tapping public capital beyond the state government's budget.

Figure 6: How to create an integrated financing strategy for Jharkhand



Source: IEEFA

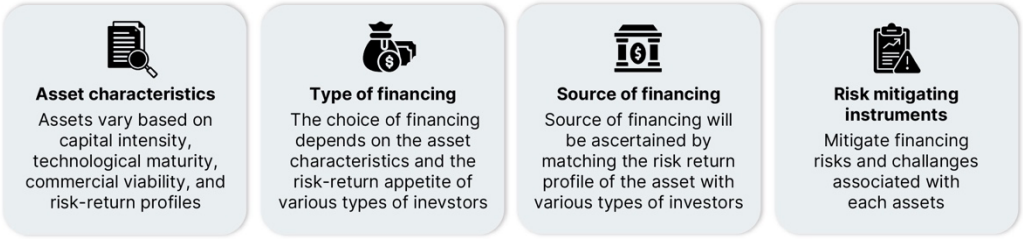
The first two steps will help estimate the costs for the closure of existing coal-based infrastructure, the setup of renewable energy assets, diversification into other low-carbon sectors and the social costs, such as workforce retraining and community development. For the last two steps, we propose a sustainable finance framework in the next section to determine potential sources of capital for each asset and economic activity based on their risk-return profiles, and assess the capacity-building needs of government stakeholders along with policy reforms needed to support the transition.

This report provides a comprehensive roadmap for Jharkhand's green transition based on these four steps, addressing its dependence on fossil fuels while promoting sustainable economic diversification. To achieve a Just Transition across all sectors, we focus on labour and community support measures to promote inclusiveness. An implementation roadmap outlines short-term (up to 2030), medium-term (2031-40) and long-term (beyond 2040) priorities, offering actionable steps for an equitable and time-bound transition in the state.

2. The sustainable finance framework

Jharkhand's green transition needs massive capital and funding to build green assets and social welfare, as well as finance the closure of coal assets. While private finances will create new green assets, reskilling people for the industry will mainly require public capital. Within green assets, financing needs also differ among various technologies, owing to technological maturity and commercial viability differences. A sustainable finance framework is essential to orchestrate this, providing a blueprint that outlines the key characteristics, financing types and sources, and necessary risk mitigation for all identified assets and other funding needs. This framework identifies suitable financing instruments, sources of capital and risk-mitigating instruments to accelerate capital mobilisation for low-carbon technologies. Besides, the framework offers a suitable pathway to finance social welfare and early retirement of carbon-intensive assets.

Figure 7: The sustainable finance framework



Source: IEEFA

Together, these four components create a comprehensive framework that supports Jharkhand's transition to a low-carbon economy, addressing all financial aspects systematically to achieve the desired socio-economic and environmental outcomes.

We evaluated several different capital providers to finance the various assets and economic activities slated for funding in Jharkhand (see Annexure).

The subsequent sections will elaborate on different assets and economic activities, including phasing out fossil fuel assets, economic diversification and Just Transition activities. Each section details the costs associated with transitioning that particular asset, and outlines a financing strategy based on the sustainable finance framework.

3. Transitioning from fossil fuel assets

As discussed earlier, Jharkhand's economy is inextricably tied to coal, which forms the backbone of its fiscal health and industrial ecosystem. As a major coal-producing state, the state plays a crucial role in meeting India's energy requirements. However, India's aim to reach net-zero emissions by 2070 will challenge this coal-dependent economy. The economic impact of these fossil fuel assets is

substantial, providing significant revenue, enhancing local infrastructure, and supporting the socio-economic framework of many districts through direct and indirect employment.

3.1 Coalmining assets

Jharkhand boasts India's second-largest coal reserves (88 billion tonnes[26]) and is a key coal producer, ranking third nationally with 191 million tonnes of coal produced during FY2023-24.[27] The state's coalmining sector remains a critical driver of its economy, providing energy for industries, and generating substantial state revenue.

Table 3: Status of coalmines in Jharkhand

Status	Type	Mines	Area (hectares)	Capacity (Mtpa)
Active	Opencast	78	38,358	246
	Underground	23	9,875	13
	Subtotal	**101**	**48,233**	**259**
Dormant	Opencast	82	33,601	0
	Underground	34	12,204	0
	Subtotal	**116**	**45,805**	**0**
Total		**217**	**94,038**	**259**
Expected capacity addition (2026-2047)			**60,643**	**326**

Sources: GEM, Jharkhand Department of Mines

Jharkhand's coalmining landscape comprises 217 mines across 94,039 hectares (ha), with a capacity of 259Mtpa.[28,29&30] Of these, 101 are active, primarily opencast mines producing 246Mtpa. The state has 116 dormant mines, covering 45,805ha.

3.1.1 Expected capacity addition

The expansion strategy of the Ministry of Coal forms the basis of this report's projections of annual capacity addition from 2025 to 2047.[31,32] It is also assumed that, in alignment with India's 2070 net-zero target, no new coalmining capacity will be added beyond 2047.

The projections suggest Jharkhand is likely to add a substantial 326Mtpa of coal production capacity over four decades (with more than half from 2026-2030), more than the state's current total capacity

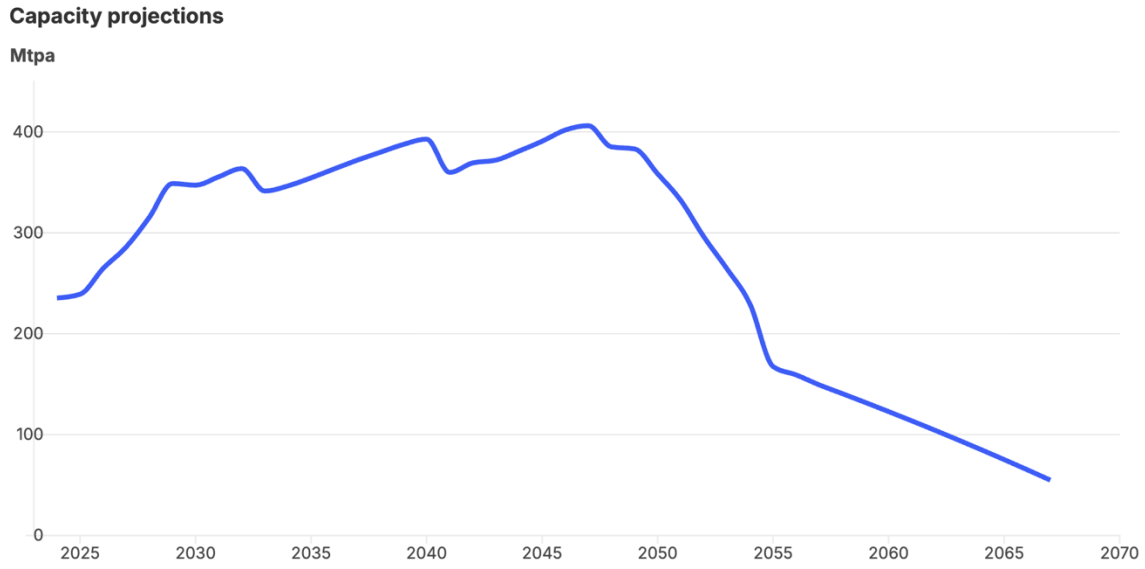
[26] Ministry of Coal. Coal reserves. April 2023.
[27] ICED NITI Aayog. State-wise Domestic Coal Production. FY2022-23.
[28] Global Energy Monitor (GEM). Global Coal Mine Tracker. May 2025.
[29] Jharkhand Department of Mines and Minerals. Coal data.
[30] Ministry of Coal. Production data. Production in October 2024.
[31] Ministry of Coal. Growth projection of coal. 22 July 2024.
[32] PSUWatch. Coal production projection by 2047. 15 February 2024.

of 259Mtpa. Hence, the projected capacity additions represent a significant increase, underscoring the state's critical role in meeting near-term energy demands in India.

3.1.2 Trajectory of coalmine closures

There are some assumptions in this report's projections for coalmine closures. India will likely stop adding new coalmining capacity after 2047, aligning with its 2070 net-zero target. It assumes a base-case scenario in which coalmine closures in Jharkhand begin in 2030 and progress towards a complete phase-out by 2070. This report also assumes dormant mines will shut upon expiry or the cut-off year of 2030, while active mines will operate until their lifecycle ends (or until 2070). The closures are projected to occur in three phases: capacity additions until 2047, stabilisation from 2047 to 2050, and a decline from 2051 as India advances decarbonisation for its 2070 net-zero goal. Strategic planning is essential to manage socio-economic impacts and ensure a smooth transition.

Figure 8: Trajectory of coalmine closures in Jharkhand



Source: IEEFA

3.1.3 Cost of coalmine closures

This report estimates the cost of coalmine closures based on the projected closure trajectory and specific cost assumptions, such as:

1. Based on government data and Jharkhand's mine lifecycle, the total costs of coalmine closures include technical closure, biological reclamation, and post-closure monitoring. As regulatory mine closure deposits are insufficient, IEEFA estimates the technical closure costs to be almost two times higher due to its elongated lifespans, high stripping ratio and heightened slopes of overburden dump.

2. For accelerated closures, mine owners receive compensation that factors in coal miners' borrowings, leverage, pricing and profit margins. Despite escrow funds, the overall financial burden remains significant. IEEFA estimates the costs of technical and biological reclamation alone at Rs2.2 trillion (US$26 billion), highlighting the need for strong financial planning.

Table 4: Cost of coalmine closures in Jharkhand, 2026-2070

Coalmine closure cost	Total cost (Rs billion)	Total cost (US$M)
Technical closure	2,13,223	25,351
Biological Reclamation	3,821	454
Post-closure monitoring	503	60
Compensation for profits	6,278	746
Coalmine reclamation cost	**2,23,825**	**26,611**
Less: Escrow for reclamation	**71,242**	**8,470**
Total Coalmine closure	**1,52,583**	**18,141**

Source: IEEFA

3.2 Thermal power plant assets

The closure of thermal power plants (TPPs) in Jharkhand will also have an impact on the coal ecosystem, which is central to the nation's energy security and economy. The state's TPPs, primarily reliant on coal, are critical in providing electricity and supporting local livelihoods. Their phased retirement, in line with India's net-zero commitments, will not only affect power generation capacity but also disrupt associated industries and employment. The transition will require careful planning to maintain energy security while mitigating socio-economic repercussions.

3.2.1 Status of TPPs in Jharkhand

Jharkhand has 34 thermal power plants with a combined capacity of 8,955MW.[33,34,35] These include eight units in the central sector with a capacity of 3,920MW, 17 private sector units producing 3,951MW, seven units with a capacity of 338MW under the Steel Authority of India Limited (SAIL) and two state sector units generating 746MW (Table 5). Of this output, Jharkhand consumes 2,607MW; 539MW is for captive use, and the balance is exported to other states.[36]

Table 5: TPPs in Jharkhand

Status	Sector	Units	Capacity (MW)
Existing	Central	8	3,920
	Private	17	3,951
	SAIL-DVC joint venture	7	338

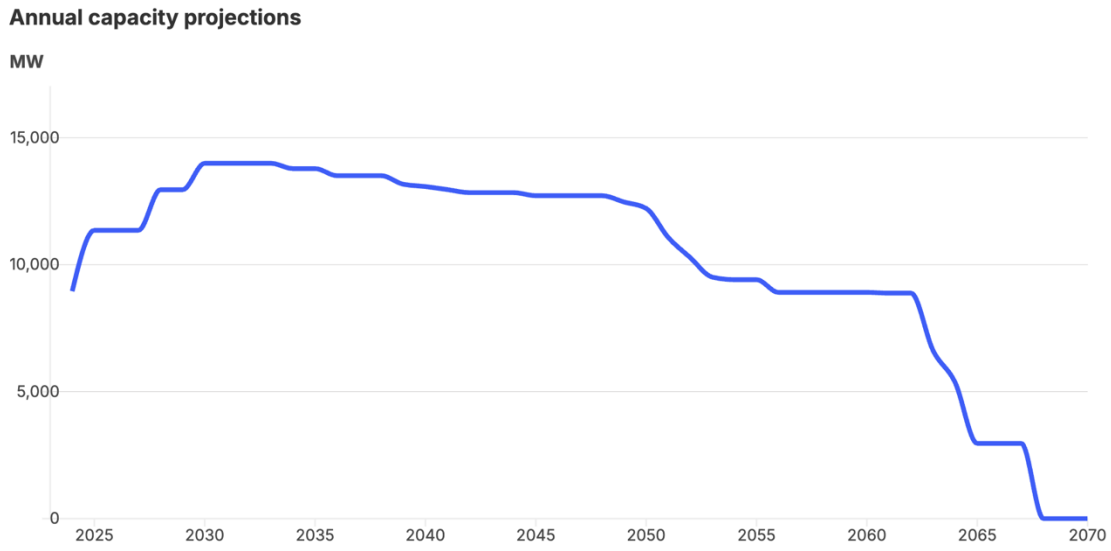
[33] CEA. List of thermal power stations. March 2023.
[34] GEM. Global Coal plants tracker. October 2024.
[35] Total capacity has been calculated based on data provided by CEA, GEM, and entity-level installed capacity data.
[36] CEA. All India installed capacity (in MW) of power stations. December 2024.

	State	2	746
	Subtotal	**34**	**8,955**
Pipeline	Central	4	3,200
	NTPC- Govt of Jharkhand joint venture	4	3,760
	Subtotal	**8**	**6,960**
	Total	**42**	**15,915**

Source: CEA, GEM

In addition to the existing capacity, eight new plants are under development with a total capacity of 6,960MW.[37] Of these, four central sector units are likely to generate 3,200MW, while four units under NTPC and the Government of Jharkhand will contribute 3,760MW. Altogether, the state is likely to have 42 TPPs with a combined capacity of 15,915MW by 2030.

Figure 9: Trajectory of TPP closures in Jharkhand



Source: IEEFA

The capacity and cost projections for TPP closures in this report are based on some assumptions, such as:

1. The projections assume TPPs will retire by the end of their lifespan. Where specific plant data was unavailable, state averages are used.
2. TPP capacity will follow a phased decline: rapid expansion until 2030, stabilisation from 2030 to 2040, a gradual decline from 2040 to 2060 as older plants retire, and a sharp drop after 2060 due to accelerated decarbonisation for the 2070 net-zero target. This approach ensures a systematic transition from coal while minimising socio-economic disruptions and supporting sustainable energy growth.

[37] CEA. Broad status report of under construction thermal power projects. August 2024.

3. Decommissioning cost estimates, including waste removal, land remediation and revenue from the sale of scrap, are based on expert consultations and secondary literature.[38]

Table 6: Cost required for TPP retirement in Jharkhand, 2030-2070

TPP Retirement cost	Total Capex (Rs Crores)	Total Capex (US$ Million)
Decommissioning cost	314	37
Ash pond closure & removal	134	16
Remediation	15	2
Compensation for profits	139	17
TPP retirement cost - Gross	**601**	**72**
Less: recovery from scrap sale	(125)	(15)
TPP retirement cost - Net	**476**	**57**

Source: IEEFA

3.3 Decommissioning coal assets: Financing and policy

As discussed in the previous section, decommissioning coalmines and TPPs will require significant capital. Additionally, accelerated closure of coal assets, both mines and TPPs, needs capital provision, especially in cases where there is a requirement to compensate asset owners for early retirement of coal capacity.

The regulations differ for decommissioning of coalmines and TPPs. Indian coalmine owners must prepare a Mine Closure Plan (MCP) for each mine, comprising progressive and final closure phases.[39] Progressive MCPs involve continuous land use activities during operations. Final closure activities begin as the mine nears the end of its life and continue until restoration is complete. Mine owners deposit the funds for closure into an escrow account, typically calculated on a per-hectare basis at prescribed rates, and deposited annually. The primary responsibility for mine closure rests with the owner. If the allocated funds are insufficient to meet the full cost of final closure, the owner must provide additional resources to cover the shortfall. Accordingly, as estimated in this report, the coalmining company will be required to bear any extra capital needed for the closure.

Unlike coalmine assets, where the mine owner must maintain a mine closure deposit in an escrow account, TPPs have no such regulations. However, the onus of decommissioning still falls on the plant owner. Given the cost of retiring a TPP exceeds the value recoverable from scrap sales, and in the absence of clear decommissioning guidelines, private operators may be reluctant to carry out closures in line with international best practices, potentially causing harm to surrounding communities and the environment.

[38] For example, Climate Risk Horizons. Financial benefits of repurposing Maharashtra's old coal plants. November 2022.
[39] Environmental Clearance. Mine Closure Plan. June 2019.

For accelerated closure, since the company is voluntarily retiring assets, it would expect to receive a lump sum compensation, which will be the present value of expected cash flows (forgone profit) until the end of the plant's life. However, arriving at a fair valuation of the decommissioned TPP to compensate the company would be challenging.[40] Negotiations among stakeholders will be critical to assessing private companies' fair recovery value.

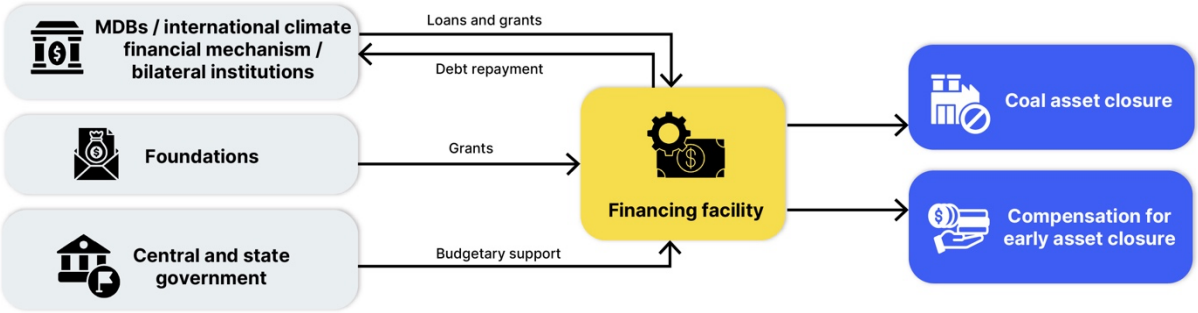
3.3.1 Financing facility to bridge funding gap

One of the mechanisms to address the funding gap is to create a coal asset retirement financing facility. This facility could be jointly established by an international development agency such as an MDB or an international climate fund, and the Government of Jharkhand. It would mobilise concessional long-term debt and grant funding from multiple sources, including budgetary support and grants from the central government, concessional loans and grants from MDBs, bilateral institutions and international climate finance mechanisms, as well as contributions from philanthropic foundations.

The facility would be used to finance the cost of decommissioning, provide compensation for early asset retirement, and cover the cost of independent third-party oversight to ensure closures are executed in line with international best practices. Decommissioned sites could then be repurposed for new, low-carbon uses.

By consolidating resources into a single financing facility, the process would benefit from improved coordination among all agencies involved in coal asset closures, while reducing transaction costs compared with raising capital separately for each mine or small cluster of mines.

Figure 10: Structure of a coal asset closure financing facility



Source: IEEFA Analysis

Precedents already exist across India that Jharkhand can learn from to create state-level facility or fund. For instance, the TNIFMC manages a range of AIF structures, including the Tamil Nadu Green Climate Fund, which is India's first state-backed, SEBI-registered AIF focused specifically on green

[40] Glasgow Financial Alliance for Net Zero. Financing the Managed Phaseout of Coal-Fired Power Plants in Asia Pacific. Webinar. 26 July 2023.

investments. This model demonstrates how a state can use an AIF vehicle to mobilise institutional investors alongside concessional anchor funding.

Similarly, the KIIFB in Kerala has established a bond-financed infrastructure vehicle that channels long-tenor debt into state projects, while the Kerala Startup Mission (KSUM) operates an FoF model, where the state comes in as a limited partner (LP) in SEBI-registered AIFs. This approach leverages private fund managers' expertise while ensuring a defined share of capital flows back into Kerala-linked enterprises.

Other states have also experimented with hybrid models. The Maharashtra Innovation & Technological Development Fund (MITDF) is a SEBI-registered AIF managed by IDBI Capital that invests directly in innovation and sustainability-linked enterprises in the state. The Odisha Startup Growth Fund, managed by SIDBI as an FoF, aggregates state and central resources and deploys them through multiple daughter funds into local businesses. Taken together, these examples illustrate the variety of governance structures and capital-stack combinations available, such as AIF structures with concessional anchors, bond-financed boards, Fund-of-Funds LP commitments, and direct state-backed venture vehicles. For Jharkhand, these models provide concrete design options for structuring a state-aligned coal asset retirement facility.

In the case of TPPs, a sustainability-linked bond (SLB)[41] offers another potential instrument to facilitate early retirement, particularly for companies intending to develop renewable energy projects. This financial instrument can be carefully designed to balance environmental and financial considerations. SLBs are based on key performance indicators (KPIs), such as emissions reductions and clean energy goals, with financial penalties for failure to meet these targets.[42]

A company with TPP assets, entering or expanding green businesses, would issue an SLB with two KPIs: (1) A decommissioning deadline for the TPP; and (2) Increasing renewable energy capacity in tandem with the TPP retirement (solar, wind, energy storage, green hydrogen or a combination) in the state. The SLB must ring-fence the use of proceeds for each KPI to ensure transparency. The company can then use the interest rate reduction from the issuance of SLBs to retire TPPs.

4. Economic diversification of Jharkhand

As Jharkhand shifts from coal dependence, economic diversification will be vital to sustaining growth, creating jobs, and offsetting revenue losses. The state has significant opportunities to position itself as a hub for low-carbon industries, leveraging its mineral wealth, industrial base and geographic advantages. Based on stakeholder consultations and a secondary literature review, IEEFA has identified several key areas for economic diversification that align with the state's needs and potential. These include:

[41] London School of Economics: What are sustainability-linked bonds and how can they help developing countries? November 2023.
[42] IEEFA. Repurposing India's coal power plants: Sustainability-linked green bonds as a financing solution. March 2023.

- Low-carbon power generation and storage assets
- Manufacturing of low-carbon technologies
- Green hydrogen production
- Energy plantations and natural farming
- Mining of critical minerals

Additional opportunities exist in agriculture and allied activities, green building, circular economy applications and IT/IT-enabled services. The following subsections analyse each sector in detail—its status, growth potential, estimated capital expenditure and financing strategies.

4.1 Low-carbon power generation and storage assets

India is firmly committed to exponentially increasing energy capacity and decarbonising the power sector. The country's total renewable energy capacity (including large hydro) was nearly 246GW as of July 2025, driven by policy and market tailwinds.[43]

The country's ambitious targets provide significant opportunities to grow the low-carbon economy in Jharkhand, which has sizeable renewable energy resources. While the share of renewables in the state's capacity is evolving, efforts are under way to expand their role in the energy mix. In July 2022, the state introduced the Jharkhand State Solar Policy 2022, aiming to achieve a cumulative solar power capacity of 4,000MW by 2027 (Tables 7).[44] However, estimates suggest a much larger potential for solar within the state along with other renewable sources.

Table 7: Installed capacity and maximum potential of renewable energy and storage in Jharkhand

Generation asset	Installed capacity (MW)	Maximum potential (MW)
Hydro	210	4,105
Solar	200	39,192
Wind	-	715
Distributed renewable energy (DRE)	-	1,740
Biomass	20	4,500
Total	**430**	**50,252**

Storage asset	Installed capacity (MWh)	Maximum potential (MWh)
Pumped hydro	4	20,209
BESS	0	70,461

[43] CEA. All India installed capacity (in mw) of power stations. 30 July 2025.
[44] Jharkhand Renewable Energy Development Agency (JREDA). Jharkhand State Solar Policy 2022. Page 1. 2022.

Sources: ICED, Centre for Environment and Energy Development, Institute of Sustainability and Environmental Professionals, Central Board of Irrigation and Power

This report estimates the cumulative capital expenditure required to unlock Jharkhand's full renewable energy and storage potential, based on the following assumptions:

1. As coal mines close and TPPs retire, there will be loss of jobs and power supply. To offset these losses, we have assumed that installation of new renewable energy assets will be prioritised within the same districts (where feasible) to minimise workforce migration and maintain supply.
2. Estimates of Jharkhand's renewable energy and storage potential are drawn from secondary literature, stakeholder consultations and Just Transition Taskforce analysis. BESS capacity is projected in line with solar PV potential and demand forecasts, considering a six-hour storage.
3. All capacity additions are capped at the state's maximum potential (based on existing studies).
4. Technology costs, lifespans and installation timelines are based on CEA estimates, factoring in projected cost trends over time.[45,46,47&48]
5. As electricity demand rises[49] and TPP supply declines, renewable energy paired with storage is assumed to meet the state's needs. We assume that the state will also contract power from assets in other renewable energy-rich states in India to fulfil its demand.

Table 8: Cumulative capex on renewable energy and storage in Jharkhand, 2026-2070

Asset	Cost (Rs Mn per MW/MWh)	Capex (Rs billion)	Capex (US$ Bn)
Hydro	200	674.5	8.0
Solar	41	1,744.4	20.7
Wind	60	42.9	0.5
DRE	49	142.9	1.7
Biomass	90	332.4	4.0
Pumped hydro (MW)	65	1,071.1	12.7
BESS (MWh)	88	807.0	9.6
Total		**4,815.1**	**57.2**

Sources: CEA; IEEFA

The successful realisation of renewable energy and storage potential in Jharkhand depends on the state's ability to make key policy decisions to encourage capital flow into these sectors. (For more detail, see Policy Levers Required to Undertake a Just Transition.) In particular, pumped hydro storage (PHS) represents a strategic opportunity. With a significant resource potential, Jharkhand

[45] Mercom India. Solar Power to Cost 15% to 25% Less in the Upcoming Decade. January 2021.
[46] US Department of Energy. Berkley Lab. Wind Power Costs Reduced Dramatically. September 2016.
[47] IEEFA. India's $2.1bn Leap Towards its Green Hydrogen Vision. March 2024.
[48] US National Renewable Energy Laboratory (NREL). Utility-Scale Battery Storage. 2024.
[49] The Energy and Resources Institute (TERI). India's Electricity Transition Pathways to 2050: Scenarios and Insights. 2023. Page 4.

can meet its own modest storage demand and still have substantial surplus PHS capacity to export firm, round-the-clock renewable power to other states. Hence, investment in PHS should be prioritised by the government as a core part of Jharkhand's transition strategy.

Jharkhand also needs to upgrade its transmission and distribution (T&D) infrastructure to ensure its grid can accommodate the renewable energy generated and transmitted within the state. The capital expenditure (capex) calculation uses cost estimates published by the Ministry of Power and the CEA. For calculating capacity upgrades, this report assumes the annual capacity addition in the renewable energy and storage segments. The report does not consider the cost of inter-state transmission systems.

Table 9: Cumulative capex for T&D upgrade in Jharkhand

Capex (Rs billion)	Capex (US$M)
509.3	6,055

Sources: CEA, Ministry of Power, IEEFA.

4.1.1 Financing mechanism and framework

Each asset considered in the renewable energy and storage segment in the above section has different characteristics from a financing standpoint. Table 10 summarises these characteristics by applying the sustainable finance framework and identifying the appropriate set of capital providers for each.

Table 10: Renewable energy and storage assets in a sustainable finance framework

	RE (utility scale)	Distributed solar	BESS	Pumped storage	Biomass
Asset Characteristics					
Capital intensive	■	■	■	■	■
Long gestation period	■		■	■	■
Medium gestation period		■			
Low to moderate tech/general risk	■	■	■	■	
Utility style	■				
Revenue uncertainty	■			■	■
Low OpEx				■	■
Low margin/loss making	■		■		
Type of financing					
Commercial loan			■		■
Bonds	■				
Public equity	■				
Proprietary equity	■	■	■	■	■
Risky equity			■		

Grant					
Concessional debt					
InVIT/securitisation/IDF					
Source of financing					
Banks/NBFCs					
Institutional investors					
DFIs/MDBs					
Govt					
Public sector financial institutions					
Corporations					
PEs/VCs					
Risk mitigation instruments					
Credit guarantee					
Payment security mechanism					

Source: IEEFA

4.1.1.1 Renewable energy (utility-scale)

Solar and wind energy projects, being capital-intensive, require substantial upfront investment to become viable and competitive with traditional carbon-intensive energy sources.[50] They depend on long-term and low-cost capital to make these technologies competitive and affordable.

Debt plays a central role in lowering the cost of renewable energy, as it is cheaper than equity, and helps make these technologies more affordable compared with TPPs. Long-term equity is also essential, given that most equity returns from renewable projects materialise years after commissioning. Developers can sell their equity stakes once projects are operational and risks have diminished, enabling them to exit and reinvest in new renewable ventures.

However, financing renewable projects entails several risks: [51]

- **Financial risks**, such as the poor financial health of electricity distribution companies (DISCOMs) leading to delayed payments for renewable energy developers.
- **Operational and policy risks**, such as land acquisition issues, grid connectivity challenges, environmental hurdles and tariff renegotiations.
- **Market and currency risks**, including foreign currency fluctuations (for foreign currency denominated debt), and refinancing difficulties.

[50] Climate Policy Initiative. Getting to India's Renewable Energy Targets: A Business Case for Institutional Investment. 2018. Page 3
[51] Bloomsbury. Net-Zero Trio: Synchronising Technology, Business and Policy for Green Transition. *Jena, L., Ashok P.* October 2024.

Financing mechanism

Utility-scale renewable energy investments require heavy upfront capex. Yet, predictable cash flows, owing to lower operational expenditure (OpEx) and technology risk, and the utility-style business model make them safe investments.[52]

Domestic banks and non-bank lenders play a central role in providing term loans, though high interest rates compared to developed markets increase the cost of capital. To deepen financing avenues, structures such as infrastructure investment trusts (InvITs), green bonds, and alternative investment funds (AIFs) have emerged as important vehicles to pool assets and attract institutional capital.

Global pension funds, sovereign wealth funds, and insurers have shown growing interest in Indian renewables, but they typically require credit-enhanced instruments to mitigate risks. Mechanisms such as payment security funds, tripartite agreements with state DISCOMs, and credit enhancement facilities[53] help reduce counterparty and revenue risks, thereby lowering borrowing costs and improving investor confidence.

Beyond national-level financial sector reforms to address broader market and currency risks, Jharkhand can implement targeted measures to improve project bankability, such as streamlining approvals, ensuring timely payments, and facilitating land and grid access. These steps, combined with clear policy direction, will be essential to accelerate renewable energy growth as part of the state's Just Transition strategy (see Policy Levers Required to Undertake a Just Transition).

4.1.1.2 Distributed renewable energy (solar)

Distributed renewable energy (DRE) offers strong potential for Jharkhand, with applications ranging from rooftop solar installations to systems for irrigation and small, ground-mounted projects. The key consumers are households, farmers, institutions (schools, hospitals and offices) and micro, small and medium enterprises (MSMEs).

Two business models dominate India's rooftop solar sector: the straightforward sales model (capex), and the renewable energy service company (RESCO) model (operating expenditure/OpEx). Under the RESCO model, the project developer owns the solar PV systems, and therefore must invest upfront.

Financing DRE projects, however, presents multiple challenges including high initial capital requirements, elevated interest rates, limited borrower creditworthiness, small ticket sizes and the need for substantial subsidies in certain consumer segments.[54]

[52] Springer Books. Innovation, Technology and Market Ecosystems. Directing Institutional Capital to India's Renewable Energy Sector. *Prakash J., Meattle C*. 2020. Pages 109-128.
[53] World Economic Forum. How de-risking renewable investments can bridge the $1.2 trillion gap in developing countries. 1 February 2024.
[54] Emerging Economy Studies. Financing rooftop solar sector: Usage of public credit guarantee. *Jena, L*. November 2023, Volume 4(1), Pages 1-10.

Financing mechanism

The financing structure for solar DRE varies by business model. In the capex model, developers typically combine equity from private investors or large solar companies with debt from banks or non-banking financial companies (NBFCs). In the OpEx model, the system owner, often a household or business, contributes equity, while debt is sourced from similar financial institutions.

To expand market access, risk-mitigation instruments such as partial credit guarantees (PCGs) and PSMs can strengthen credit profiles and improve borrowing terms. For consumer segments with limited repayment capacity, such as farmers and low-income households, targeted concessional loans and grants are critical to make adoption financially viable.

4.1.1.3 Battery energy storage systems (BESS)

BESS is a long-term investment with a lifespan of about 20 years, extendable with battery upgrades, requiring ongoing capital commitment. Battery costs dropped by more than 80% in the decade from 2013 to 2023, and continued to decline, from US$144/kWh in 2023 to US$115/kWh in 2024[55]. Nonetheless, the technology remains expensive, making it challenging to attract long-term investors due to high financial risks.[56] Its inability to compete with lower-cost energy sources such as thermal power and pumped hydro storage further complicates scaling up BESS. Achieving grid parity will likely take more time for BESS projects, although it has achieved grid parity in some segments such as industrial and commercial consumers in top states.

Financing BESS projects carries several risks and challenges, including limited revenue sources, massive upfront capital investment, technology risk and lack of a well-developed supply chain and infrastructure.[57]

Financing mechanism

The industry landscape means BESS investments are best suited to corporations, such as renewable energy developers or battery manufacturers and, to a lesser extent, private equity (PE) funds investing through start-ups. Heavy reliance on PE funding, however, could raise project costs, and slow large-scale adoption. While corporations are likely to continue providing equity, expanding deployment will require mobilising debt and equity from institutional investors and banks.

Jharkhand can tap central government support, international climate finance from MDBs, and other climate finance mechanisms to secure concessional loans for BESS projects. These funds could be strategically deployed, such as through blended finance structures, to enhance project creditworthiness and attract additional private capital.

[55] PV magazine: Lithium-ion battery pack prices drop. 12 December 2024
[56] Renewable Watch. Strengths and challenges of BESSs and PSPs in the Indian context. 6 September 2024.
[57] Journal of Energy Storage. A review of energy storage financing – Learning from and partnering with the renewable energy industry. *Miller L., Carriveau R*. October 2018. Volume 19. Pages 311-319.

4.1.1.4 pumped hydro storage

Like hydro plants, pumped hydro storage projects (also known as pumped storage projects or PSP) are land- and capital-intensive, with long construction periods due to extensive approvals.[58] They also face uncertain revenues and potential environmental impacts. Typically, DISCOMs operate PSPs on a cost-recovery basis rather than for profit.[59] The uncertain revenue and potential ecological impact costs make banks and investors hesitant to provide low-cost, long-term debt capital.

Financing mechanism

PSPs, although less risky, have associated regulatory and revenue risks. Concessional capital is still necessary as profitability is not meaningful enough to attract commercial lenders. PSMs can address revenue uncertainty and improve the credit profile of borrowers. Better revenue certainty can support these projects to borrow from banks and NBFCs. Public and private corporations are potential equity investors in PSPs.

The limited return on investment makes it extremely challenging to attract equity capital from financial investors (e.g. PEs and institutional investors). To attract private investment, differential pricing mechanisms could make pumped storage projects profitable. Guarantees against post-construction liabilities could stabilise cash flow, appealing to low-risk investors. State incentives, such as stamp duty exemptions, concessional land rates, avoidance of double taxation, and state GST relief, along with generation-based incentives, could further encourage investment in PSPs.

4.1.1.5 Biomass

Like other clean energy technologies, biomass is a capital-intensive technology. Biomass power plants have a longer construction period than solar projects, of about two years.[60] Yet, the capex costs of biomass technology are decreasing, attributed to improved process integration, novel processing routes, learning curves, innovation and the use of existing infrastructure (co-location and repurposing equipment).[61]

Unlike other renewable technologies, biomass projects have higher OpEx. Operating costs include buying large volumes of organic waste (agriculture or wood), waste transportation, repairs, maintenance and upgrades.[62] In addition, acquiring a long-term biomass feedstock supply is a key challenge for such projects.

[58] India Energy Storage Alliance. Knowledge paper on Pumped Storage Projects in India. World Utility Summit. Page v.
[59] Mongabay. India's norms for pumped storage hydro projects aim to facilitate energy storage. March 2023.
[60] International Renewable Energy Agency. Biomass for Power Generation. June 2012. Page 39.
[61] US Department of Energy. Office of Energy Efficiency & Renewable Energy. Integrated Strategies to Enable Lower-Cost Biofuels. July 2020. Pages 14-18
[62] Energy Strategy Reviews. Developing biomass energy from agricultural by-products in the context of trade development. *Nguyen, T. K. C., Toan, N. Q*. July 2024. Volume 54. Pages 4-5.

Financing mechanism

Biomass projects require high upfront capital and have volatile OpEx, making cash flow unpredictable. Due to limited profitability, they rely on grants and concessional debt from government institutions, MDBs and climate finance mechanisms, while commercial debt comes from banks and NBFCs. Financial incentives reduce costs, but developers must still bear some risk. Ensuring a steady supply of raw materials through long-term contracts can mitigate risks and enhance creditworthiness. Public and private corporations may provide equity, but low returns make attracting financial investors challenging. Additionally, the small project size and lack of profitable records hinder capital raising from public markets.

4.2 Manufacturing of low-carbon technologies

As India advances toward its medium- and long-term decarbonisation goals, several sectors will face disruption, while new ones will emerge, driven by opportunities in the low-carbon transition. Given the nation's heavy reliance on these technologies, key industries such as solar PV modules and BESS manufacturing are crucial for India's energy security. However, the domestic supply chain for these sectors is underdeveloped.

A key enabler for scaling low-carbon technology manufacturing is the assured availability of essential raw materials. Jharkhand holds a unique advantage in this regard, with the highest concentration of 12 identified critical minerals among all Indian states.[63] (For more on this, see Mining of Critical Minerals Essential for the Energy Transition).

This section focuses on the state's prospects for developing three priority manufacturing sectors: solar PV modules, BESS and EVs. The proposed timeline to build these industries is aligned with the phased closure of coal assets, to minimise workforce displacement and reduce the risk of both inter- and intrastate migration.

4.2.1 Solar PV module manufacturing

Historically, India has been a major consumer and importer of solar PV modules, but favourable policies and rising demand have driven a rapid expansion in domestic manufacturing. Policies such as Domestic Content Requirements (DCR)[64] and the Production-Linked Incentive (PLI)[65] scheme have fuelled this growth by boosting demand and providing financial incentives.

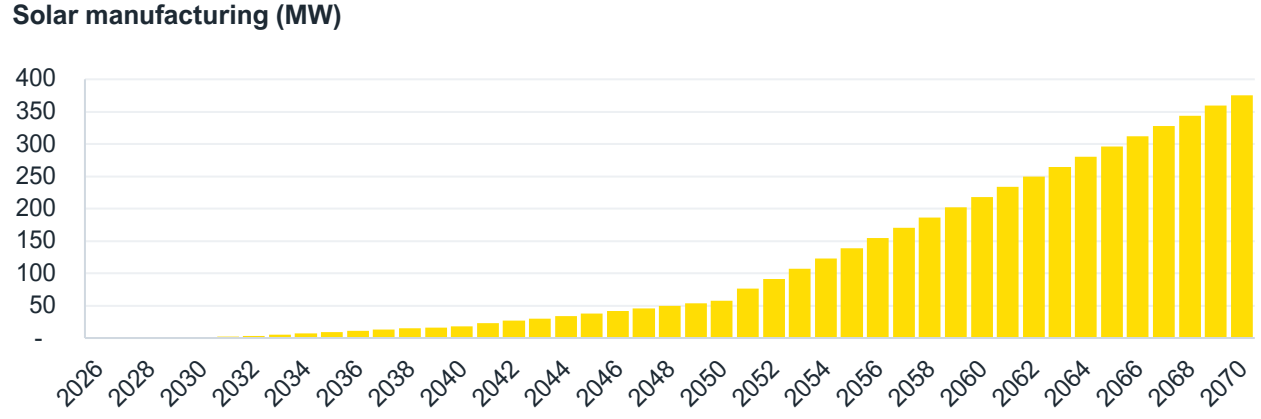
[63] CEED. Powering the Future: HYPERLINK "https://ceedindia.org/press-release/powering-the-future-critical-minerals-for-energy-transition-in-jharkhand/"Critical Minerals for Energy Transition in Jharkhand. 20 June 2024.
Critical Minerals for Energy Transition in Jharkhand. 20 June 2024.
[64] Waaree Energies. An Ultimate Guide on DCR Solar Panel. April 2024.
[65] Ministry of New and Renewable Energy. Production Linked Incentive (PLI) Scheme: National Programme on High Efficiency Solar PV Modules. August 2025.

With a target of 500GW[66] of installed renewable energy capacity by 2030, India's solar sector continues to expand. This presents opportunities for states such as Jharkhand, which, due to its strategic location and mineral resources, is well positioned to enter solar PV module manufacturing and contribute to economic growth and renewable energy goals.

India's solar PV module manufacturing capacity is projected to reach 180GW by 2030,[67] driven by policy incentives and decarbonisation goals.[68] As of August 2025, India had close to 100GW[69] of solar module manufacturing capacity, and a significant portion of its production is exported to other countries.[70] Leveraging its reserves of critical minerals, Jharkhand could enter the solar manufacturing market and target capturing 10% market share, including domestic demand and exports, by 2070.

This analysis draws on case studies from facilities in Tamil Nadu and Maharashtra to inform assumptions on capital expenditure, production costs, job creation and plant capacity.[71,72,73] It is based on a fully integrated manufacturing set-up utilising Jharkhand's potential silica reserves (although further feasibility assessments will be required).[74] This report outlines the estimated capacity Jharkhand could add between 2026 and 2070 (Figure 10), with capex adjusted for inflation (Table 11), and findings validated through expert consultations.

Figure 11: Projected cumulative solar module manufacturing capacity in Jharkhand (MW)



Source: IEEFA

[66] PIB. Government declares plan to add 50 GW of renewable energy capacity annually for next 5 years to achieve the target of 500 GW by 2030. 5 April 2023.
[67] JMK Research & Analytics. Solar PV Manufacturing in India: Trends and Opportunities.
[68] Fortune India. The future of solar manufacturing in India. 18 December 2024.
[69] PIB. Press Release. 13 August 2025
[70] IEEFA. Indian solar PV exports surging. November 2024.
[71] Vikram Solar. DFC and Vikram Solar Sign Ceremonial Retainer. 18 December 2023.
[72] Times of India. Tata Power RE expansion investment plans. 18 September 2024.
[73] Waaree Energies. Capital Expenditure Report. 7 October 2024.
[74] EQ Magazine. India lacks silica to make solar panels: Govt. 9 March 2021.

Table 11: Solar module manufacturing potential and capex in Jharkhand

Annual Production by 2070 (MW)	Jharkhand production as % of India's	Total Capital Expenditure (Rs Crores)	Total Capital Expenditure (US$ Million)
375	10%	5,76,916	68,591

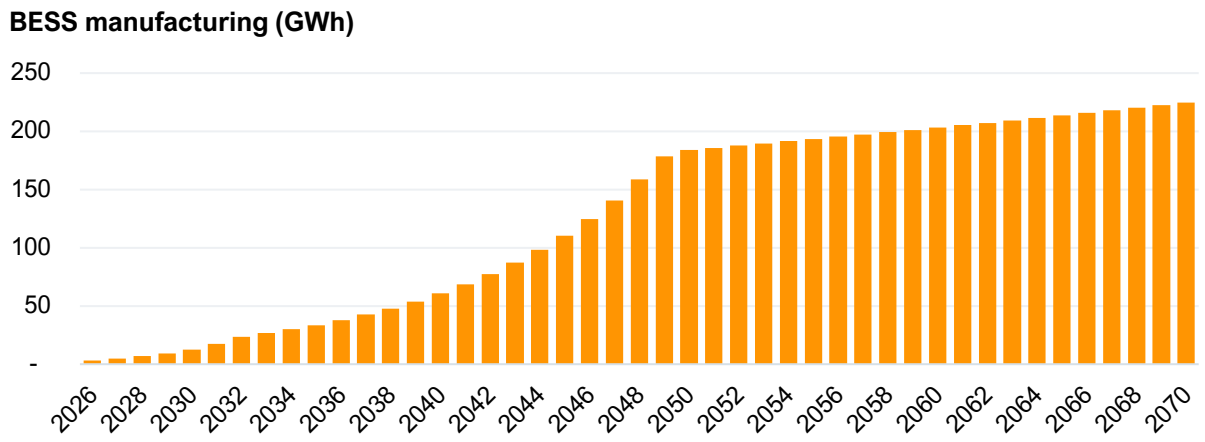
Source: IEEFA

4.2.2 BESS manufacturing

A second sector that will benefit from the country's transition towards low-carbon generation is stationary storage. The CEA estimates a need for about 8.5GW of BESS projects by FY2026-27 and close to 47GW by FY2031-32 to enhance grid stability amid increasing renewable energy penetration in the country.[75] According to industry estimates, there is a funding opportunity of Rs3.5 trillion by FY2031-32 in India's BESS manufacturing sector.[76]

A critical driver of this growth will be domestic manufacturing and a cradle-to-grave approach to the battery value chain, with the central government's Production Linked Incentive (PLI) scheme providing an important foundation.[77] Jharkhand, with its reserves of lithium (needs further exploration), cobalt, and nickel, is well-positioned to develop a competitive BESS manufacturing industry.

Figure 12: Projected cumulative BESS manufacturing capacity in Jharkhand (GWh)



Source: IEEFA

[75] CEA. India's need power transmission for 500 GW RE capacity. December 2022.
[76] pv magazine. India's expanding battery energy storage ecosystem presents INR 3.5 trillion investment opportunity till FY 2032. 6 November 2024.
[77] The Hindu. India's battery storage boom: 12-fold growth expected by FY32 with 60 GW capacity. 6 November 2024.

This report makes key assumptions for capacity and cost projections for BESS manufacturing in Jharkhand. India's battery manufacturing capacity is likely to reach 236 gigawatt-hours (GWh) by 2031, and to 1,840GWh by 2050, with BESS costs expected to drop by up to 70%.[78,79]

To inform capital expenditure, cost structure and employment estimates, this analysis draws on comparable facilities in Odisha and Karnataka.[80,81] Based on Jharkhand's existing manufacturing infrastructure, the state could target to produce about 224GWh of BESS annually by 2070, capturing approximately 10% of domestic demand. These projections have been validated through expert consultations to ensure feasibility and accuracy.

Table 12: BESS manufacturing potential and estimated capex in Jharkhand

Yearly production capacity by 2070 (GWh)	Total Capital Expenditure (Rs Crores)	Total Capital Expenditure (US$ Million)
224	1,04,176	12,386

Source: IEEFA

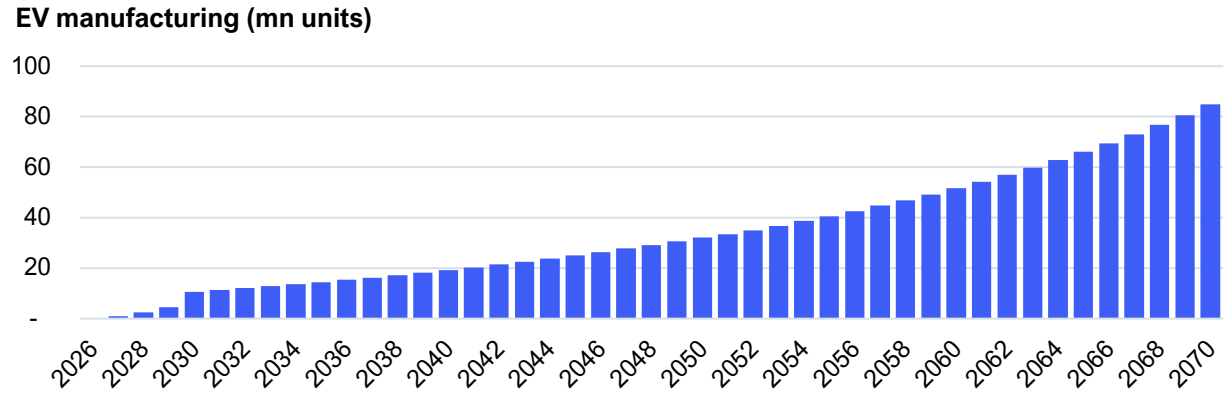
4.2.3 EV manufacturing

India's EV manufacturing sector has witnessed significant growth, fuelled by government initiatives, rising consumer awareness and robust investments from domestic and international players. Valued at about US$8.5 billion in 2024, the Indian EV market is projected to grow at an impressive CAGR of 40.7% from 2025 to 2030.[82]

Jharkhand is actively advancing sustainable mobility through initiatives such as its EV Policy (2022)[83] and the adoption of Bharat Stage VI emissions standards. The state plans to electrify its railway network and is developing industrial and high-speed transport corridors.[84] Its Adityapur Industrial Hub, eastern India's largest automotive cluster, hosts about 1,500 industries, of which roughly 85% are engaged in manufacturing automotive components.[85]

[79] MNRE. Energy Storage Systems(ESS) Overview.
[80] Economic Times. JSW group not withdrawing Rs 40,000 cr EV project from Odisha: Company official. 24 September 2024.
[81] Mercom India. Rajesh Exports Signs Agreement for 5 GWh Lithium-Ion Cell Factory in Karnataka. 5 January 2023.
[82] Grand View Research. India Electric Vehicle Market Size & Trends. 2024.
[83] Clean Mobility Shift. Jharkhand EV policy. 2022
[84] CEED. Enabling Sustainable Mobility in Jharkhand. 15 May 2024.
[85] Business Standard. Eastern India's largest auto cluster seeks to emerge from Tata shadow. 25 May 2024.

Figure 13: Projected cumulative EV manufacturing capacity in Jharkhand (million units)



Source: IEEFA

Jharkhand's push to grow its low-carbon mobility sector, supported by a strong automotive manufacturing base, established supply chains and access to critical minerals for EV battery production, positions it well to expand into EV manufacturing.

This report's capacity and cost projections for EV manufacturing in Jharkhand are based on certain assumptions. India's EV manufacturing capacity is projected to reach 10 million units by 2030 from 2 million units in 2024 and further expand at a significant rate, such that more that 75% of India's passenger vehicle on road by 2050 will be electric, contributing to increase in EV adoption and achieving India's decarbonisation goals.[86,87,88,89] Insights from facilities in Tamil Nadu, Karnataka and Maharashtra, developed by corporate entities inform the capital expenditure, cost structure and employment estimates presented here.[90,91,92]

With its robust automotive sector and potential access to raw materials for BESS, Jharkhand could aim to capture 10% of national EV manufacturing capacity, producing about 85 million units annually by 2070, catering to both domestic and export demand.

Table 13: EV manufacturing potential and estimated capital expenditure in Jharkhand

Yearly production Capacity by 2070 (million)	Total Capital Expenditure (Rs Crores)	Total Capital Expenditure (US$ Million)
85	4,77,982	56,828

[86] Business Standard. Indian EV market potential likely to touch Rs 20 trillion by 2030: Gadkari. 10 September 2024.
[87] Astute Analytica. Electric Vehicle Market. 13 March 2025.
[88] Economic Times. EV sales in India to reach 10 mn units by 2030, to create 5 mn jobs: Nitin Gadkari. 10 September 2024.
[89] Astute Analytica. Electric Vehicle Market. 13 March 2025.
[90] Hindustan Times. Key facts to know about Ola factory, world's largest for two-wheelers. 26 February 2021.
[91] Business Standard. VinFast signs deal for Rs 16,000 crore integrated EV facility in Tamil Nadu. 7 January 2024.
[92] Mint. Ather Energy to invest ₹2,000 crore to set up third plant in Maharashtra. 27 June 2024.

Source: IEEFA

4.2.4 Financing mechanism and framework

Each asset considered in the low-carbon manufacturing segment in the preceding section has different characteristics from a financing standpoint. The figure below summarises these characteristics by applying the sustainable finance framework and identifying the appropriate set of capital providers for each.

Table 14: Characteristics of the manufacturing sector as sustainable finance framework

	Solar PV	BESS	EV
Asset characteristics			
Capital-intensive			
Long gestation period			
Medium gestation period			
Low to moderate technical/general risk			
Revenue uncertainty			
Low OpEx			
Low margin/loss-making			
Moderate margin			
Type of financing			
Commercial loan			
Bonds			
Public equity			
Proprietary equity			
Risky equity			
Grant			
Concessional debt			
InVIT/securitisation/IDF			
Source of financing			
Banks/NBFCs			
Institutional investors			
DFIs/MDBs			
Government			
Public sector financial institutions			
Corporations			
Farmers/communities			
PEs/VCs			
Risk-mitigation instruments			
Credit guarantee			

Source: IEEFA

4.2.4.1 Solar PV manufacturing

Heavy capital intensity and lower revenue per unit (solar panel), a rare and undesirable combination of lower margins, characterise solar PV manufacturing. Usually, capital-intensive industries have high operating margins. The rapid decline in solar PV prices, due to innovation, learning rate and economies of scale, has supported the rapid addition of solar to the energy system.[93] However, the excess solar PV manufacturing capacity in the global market and competition among manufacturers to utilise the most from high capacity is reducing prices further, resulting in thin operating margins.[94] Government support for homegrown solar PV manufacturers keeps these manufacturers afloat.

Financing mechanism

Given the sector's high capital requirements and prolonged periods of low or negative returns, sustained capital infusion and policy support are essential until the industry becomes self-sustaining. Patient equity, concessional debt and targeted grants will be critical over the medium to long term. Large public and private corporations with strong balance sheets are the most viable equity investors, complemented by private equity funds willing to commit capital over extended time frames.

On the debt side, concessional financing from state-owned development banks and other public financial institutions can help reduce borrowing costs. PCGs can further enhance creditworthiness, enabling manufacturers to secure debt on favourable terms. The central government's continued grant support will be vital, given the sector's strategic role in ensuring energy security. However, limited returns make direct institutional equity investment difficult to attract, reinforcing the need for long-horizon private equity and strategic corporate participation.

4.2.4.2 BESS manufacturing

Battery manufacturing is a capital-intensive business that requires significant investment in working capital.[95] Major expenditures include equipment, land, and building costs, with capital cost per unit of production (GWh) decreasing as manufacturing capacity increases, lowering battery costs through economies of scale.[96]

The sector's long construction lead time, typically 36 months,[97] means investors face a prolonged period with no cash inflows. Margins remain thin due to intense global competition from established manufacturing hubs in China, Europe and the US. Additionally, unlike some industrial equipment

[93] US NREL. Spring 2024 Solar Industry Update. May 2024. Pages 14-15.
[94] Energy AI. A comprehensive review of machine learning applications in energy systems. *Zhang, Y., Li, X., & Wang, J.* 2024. Volume 5.
[95] iScience. Current and future lithium-ion battery manufacturing. *Liu Y., Zhang R, Wang J., Wang Y.*, April 2021. Volume 24.4.
[96] Center for Study of Science, Technology and Policy. Indigenisation of lithium-ion batteries in India: A techno-economic feasibility study. June 2018. Pages 12-13.
[97] Ibid. Page 8.

sectors, battery manufacturing offers limited after-sales revenue streams, making profitability highly dependent on achieving large production volumes for EVs and stationary storage.

Financing mechanism

Given the structure and state of the battery manufacturing industry, establishing a competitive BESS sector requires substantial upfront investment. The optimal capital structure combines patient, long-term equity during the construction phase with medium- to long-term debt once operations commence. Mezzanine financing can be used to fill funding gaps during the build phase, although it comes at a higher cost. Large corporations with strong balance sheets and established battery operations are well placed to leverage their credit strength to raise construction-phase debt.

Due to the sector's modest profitability, particularly in the early years, grants and concessional loans remain essential to attract private investment. Likely equity sources include existing battery manufacturers seeking expansion, EV producers moving upstream to secure their supply chains, and credible start-ups in battery manufacturing. Private equity funds with a long investment horizon may also participate, although limited returns make direct institutional equity investment difficult to secure.

On the debt side, domestic public financial institutions can provide concessional capital, while PCGs can improve creditworthiness and enable access to larger or more affordable loans. Continued central government support will be critical, given the industry's strategic importance in accelerating renewable energy integration and reducing reliance on imported batteries.

4.2.4.3 EV manufacturing

Like many other low-carbon technologies, EV manufacturing is a capital-intensive business.[98] It requires substantial investments in production capacity, significant overhead costs, ongoing expenditure on research and development (R&D), large inventories to meet demand, and credit facilities for distributors where manufacturers lack their own retail outlets.

However, a key dilemma remains: Most EV manufacturers are yet to turn a profit, largely due to overcapacity built in anticipation of surging sales, and the burden of high battery costs.[99] The prevailing expectation is that battery prices will decline, as they have since early 2000s, and that governments will continue to drive EV adoption. This requires companies to absorb losses for several years before reaching profitability.

Established automakers can redirect capital from internal combustion engine production to EVs, leveraging existing supply chains. In contrast, start-ups, especially those dependent on external funding, face greater challenges, particularly PE investors with long investment gestation periods.

[98] Transportation Research. Part D: Transport and Environment. Decoding US investments for future battery and electric vehicle production. *Yang H., Fulton L.* May 2023. Volume 118.
[99] Economic Times. EV Industry in India Is Not Relevant without Incentives: Bernstein. 26 September 2024.

These PEs typically back EV manufacturers with the expectation of eventual stock market listings to secure their exit.

For Jharkhand, the strongest opportunity lies in attracting pure-play EV manufacturers and their supply chains, rather than competing for expansion projects from established automakers in Tamil Nadu, Gujarat and Haryana that can build on existing facilities. These companies are less likely to invest in Jharkhand. The start-ups building manufacturing facilities from scratch and fixing their supply chain would move to states that offer incentives. Besides, they would prefer to set up facilities close to battery manufacturing units for easier and cheaper logistics. It is also important to attract EV equipment suppliers, similar to the ecosystem of internal combustion engine vehicles. The state's Adityapur Industrial Hub offers a ready ecosystem that can be leveraged to serve the EV industry.

Financing mechanism

The key equity source can be existing vehicle manufacturers and battery manufacturing companies that want to enter the downstream business. PE-backed start-ups that have entered EV manufacturing are another source of equity. As the return on investment is limited, attracting equity directly from institutional investors is extremely challenging. As most pure-play EV manufacturers are making losses, raising debt from commercial banks will be difficult. However, large corporations can raise debt by leveraging their balance sheet. The central government will be a source of grants, given the industry is of strategic importance to the clean transportation sector.

4.3 Green hydrogen production

India is rapidly enhancing domestic green hydrogen production to drive its energy transition and meet climate goals. The National Green Hydrogen Mission (NGHM), launched in 2023, aims to achieve an annual production capacity of at least 5Mt of green hydrogen by 2030.[100] By 2050, India's green hydrogen production costs are expected to drop to a low of US75¢/kg, making it one of the most cost-effective producers globally.[101]

India's current hydrogen demand is estimated at 6Mt.[102] Establishing green hydrogen hubs will accelerate India's green hydrogen sector by centralising production, storage and distribution, aiding industrial decarbonisation, especially in sectors such as steel manufacturing. These hubs require co-located production facilities and offtaking industries to ensure efficient adoption.

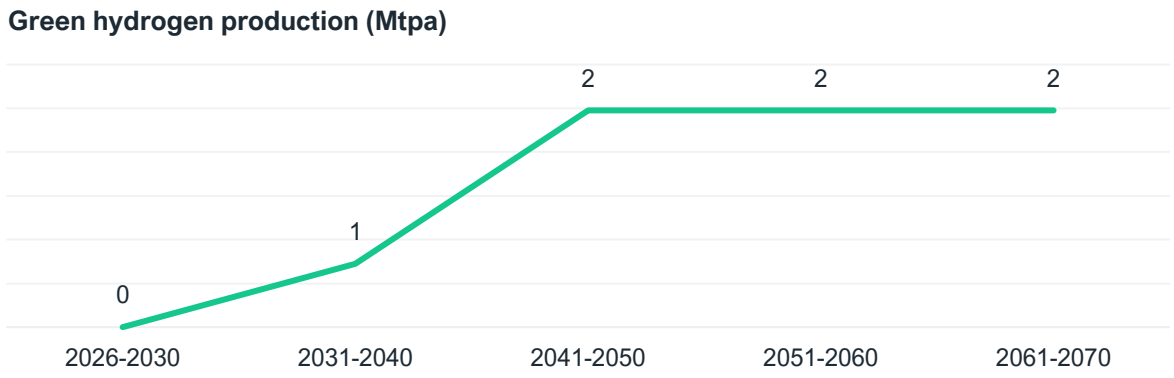
Jharkhand's large integrated steel plants (ISPs), including Tata Steel and SAIL, provide a strong base for green hydrogen adoption, serving as anchor consumers. Expanding green hydrogen production could also attract greenfield low-carbon steel units. To support this, the state has established a

[100] PIB. National Green Hydrogen Mission: Transforming India's Energy Landscape. 23 June 2024.
[101] New Climate Institute. The Landscape of Green Hydrogen in India. November 2023. Page 4.
[102] Ibid.

Green Hydrogen Sub-Task Force under the Sustainable Just Transition Task Force to develop an implementation plan.[103]

In addition to steel, demand arising from heavy goods vehicle (HGV) used in coal mining has been included as another major driver of green hydrogen uptake. Close to 168 thousand[104] heavy duty trucks are currently operating in Jharkhand, running almost entirely on diesel, with a large majority serving the coal mining sector. As coal production in Jharkhand is projected to continue growing until 2047, these vehicles will need to be replaced and expanded. Green hydrogen fuel cells are projected as a viable alternative than EVs for heavy trucks. Building this demand will also require a distribution network of hydrogen refuelling stations strategically located near mines and transport corridors. Over time, as coal production phases down, the hydrogen trucking fleet established in Jharkhand can be redeployed in the expanding critical minerals industry, ensuring long-term utilisation of the infrastructure and vehicles.

Figure 14: Cumulative green hydrogen production capacity projection in Jharkhand (Mtpa)



Source: IEEFA

This report has used some assumptions for its capacity and cost projections for green hydrogen production in Jharkhand. It assumes India's green hydrogen production capacity will reach 5Mtpa by 2030, driven by policy incentives, and expand to 55Mtpa by 2050 at a 13% CAGR.[105,106] Analysis of capex and operations of companies such as Reliance Industries, Adani Group and GreenH has informed cost structures, job potential and production capacities.[107,108,109] Electrolyser and equipment costs are expected to decline, halving green hydrogen production costs by 2030, and further reduce

[103] Government of Jharkhand. Task Force – Sustainable Just Transition. Green Hydrogen Mission. 2024.
[104] CEED.
[105] PIB. National Green Hydrogen Mission targets a production capacity of 5 Million Metric Tonnes (MMT) per annum by 2030. 9 February 2023.
[106] Economic Times. India to produce 55 million tonnes of green hydrogen in 2050. 19 June 2023.
[107] Bioenergy. India's Reliance Industries to invest $10bn in green hydrogen project. 8 January 2024.
[108] Business Standard. Adani Group starts India's biggest hydrogen blending in natural gas project. October 2024.
[109] GreenH Electrolysis. GreenH Electrolysis entered into a contract to build a Hydrogen production and Refueling station to power India's first Hydrogen train. 2024.

to US$1.23-US$1.85/kg by 2050.[110,111] It is assumed that renewable energy sourcing for production will be through the national grid.

For hydrogen demand from transport, it is assumed that 2035 onwards, 10% of new heavy vehicles in coal mining sector will be hydrogen fuel cell based, as the technology becomes commercially viable. This conversion rate is assumed to grow to 35% in 2045, reaching 100% only in 2065[112] (catering to any residual demand from existing coal mines). Given Jharkhand's strong iron and steel sector and assumed HEV demand, the state can cater to a peak demand of 2.4 MTPA of green hydrogen by 2065.

Table 15: Green hydrogen production potential and estimated capex in Jharkhand

Yearly production by 2070 (Mt)	Capex (Rs crores)	Capex (US$ Bn)
2.4	35,600	4.3

Source: IEEFA

4.3.1 Financing mechanism and framework

Green hydrogen production is an asset-heavy business with a long investment cycle, sometimes close to 20 years. It requires significant upfront capital, particularly for electrolysers, a key technology to produce green hydrogen.[113] In addition, green hydrogen production is still not profitable, and costs more than "grey" or "blue"[114] hydrogen.[115] Technological innovation is expected to reduce the cost of electrolysers, and eventually make green hydrogen more commercially viable. However, it will take time and high-risk capital until mainstream private investors participate. Corporations and PE funds are investing in the technology, but green hydrogen projects need concessional capital through grants, subsidies and concessional debt to accelerate their adoption.

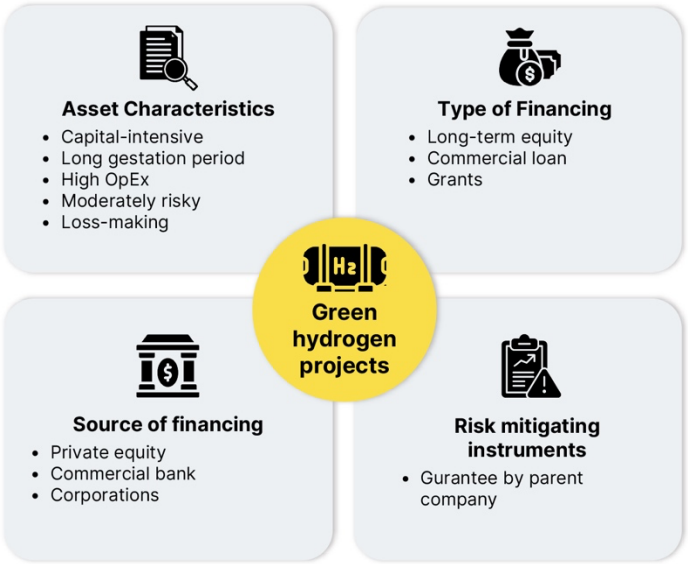
Financing mechanism

Key equity sources include renewable energy companies, steel companies and large corporations. PE-backed start-ups are another source. Until green hydrogen is profitable, raising debt from commercial banks will be difficult. However, large corporations can raise debt by leveraging their balance sheets. Green hydrogen projects need long-term concessional debt to reduce the cost of capital and make projects attractive for equity investors.

[110] PwC. The green hydrogen economy: Predicting the decarbonisation agenda of tomorrow. 2025.
[111] DD News. The Road to Affordable Green Hydrogen: A Path to Clean Energy. 14 January 2025.
[112] ArthurDLittle. Demystifying the Future of Hydrogen Mobility in India. June 2023
[113] International Journal of Hydrogen Energy. Green finance and the economic feasibility of hydrogen projects. *Taghizadeh-Hesary F. et al*. July 2022. Volume 47/58, Pages 24,511-22.
[114] Grey and Blue Hydrogen. What are grey, blue and green hydrogen. July 2021
[115] Applied Energy. Profitability of hydrogen production: Assessment of investments in electrolysers under various market circumstances. *Veenstra A., Mulder M.* December 2024. Volume 375.
[116] NBM. National Bamboo Mission.

The central government will be a source of grants, given that the industry is strategically important to the energy, steel and cement industries, and export markets.

Figure 15: Financing framework for green hydrogen projects



Source: IEEFA

4.4 Energy plantations & natural farming

Energy plantations (such as bamboo) and natural farming offer Jharkhand a pathway to diversify its agri economy into low-carbon, higher-value activities. Together they can supply clean feedstock for industry and transport, reduce farm input costs through bio-inputs and biochar, and enable monetisation of carbon credits under credible registries. These approaches align with national programmes including the National Bamboo Mission[116] and the National Mission on Natural Farming[117], both active in the state. Jharkhand's Department of Rural Development has launched the Birsa Harit Gram Yojana[118] to support more than 100,000 farmers over 20 years to utilise carbon finance for sustainable land-use. This can be extended to energy plantations and natural farming, complementing other national schemes.

[116] NBM. National Bamboo Mission.
[117] Natural Farming. National Mission on Natural Farming.
[118] My Scheme. Birsa Harit Gram Yojana.

Energy plantation

This report uses some assumptions to project the capacity and costs for adopting energy plantation in Jharkhand. About 684,300ha of wasteland outside forest areas could be utilised[119], though this will require careful land-use mapping and community consultation to ensure land tenure security and avoid conflict with existing uses. The state could target converting 20% of this land between 2026 and 2070, including areas dependent on the coal economy. For this analysis, bamboo has been assumed as the primary energy plantation crop given its suitability to degraded soils and its demonstrated energy and industrial use cases.

Capex is estimated using data from comparable projects in India and adjusted for Jharkhand's terrain. The estimate covers cost of establishing Bamboo plantation, as well as the processing infrastructure. Processing costs include palletisation units that convert bamboo biomass into energy-grade pellets. These are assumed to be built in 25,000 tonne/ year capacity blocks, scaled as plantation biomass becomes available. A provision of 15% over pellet plant capex has been included to cover logistics and storage infrastructure, such as aggregation centres, silos, and conveyors, which are critical for reliable supply chains.

Table 16: Energy plantation estimated capital expenditure in Jharkhand from 2026-2070

Total Capital Expenditure (Rs Crores)	Total Capital Expenditure (US$ Million)
6,126	728

Source: IEEFA

Natural farming

Natural farming offers Jharkhand a complementary, low-cost pathway to improve soil health, climate resilience and farm incomes alongside energy plantations. It aligns with the National Mission on Natural Farming and can build on the state's initiatives. The modelling assumes that natural farming will expand on existing rainfed cropland[120], which is held constant through 2070, with a long-run adoption target of 75% by 2070, equivalent to around 15,00,000 hectares. Adoption is phased gradually, with early years focused on capacity building, scaling up in the middle period, and tapering in later years.

Capital expenditure is assumed for programmatic support needed to scale up natural farming. Per-hectare transition support is assumed for training, extension, on-farm bio-input preparation and initial soil restoration, indexed at 5% per year. Bio Input Resource Centres (BIRCs) are also factored in.

[119] India Water Portal. Jharkhand's agroforestry potential. March 2023.
[120] ICAR. Jharkhand.

Table 18: Natural farming estimated cost in Jharkhand from 2026-2070

Total Capital Expenditure (Rs Crores)	Total Capital Expenditure (US$ Million)
3,346	398

Source: IEEFA

Additional opportunities, not included in this cost assessment but which have the potential to be scaled up significantly, include establishing torrefaction units and biochar hubs linked to plantation clusters, as well as supplying biofuel blending feedstock for ethanol via plantation biomass and residue offtake with refineries. Viability here will depend on the clustering of ethanol plants and the availability of long-term state-industry contracts to address aggregation and transport costs. There is also scope to develop nature-based solutions such as soil-carbon farming, and watershed restoration that can generate carbon revenue and build climate resilience.

4.4.1 Financing mechanism and framework

Energy plantations, and natural farming represent distinct land-use asset classes, functioning both as a commodity and a long-duration investment. They can generate multiple revenue streams like biomass for energy use, biochar, organic inputs, and carbon credits, while delivering environmental and social benefits. However, these assets face notable risks including complex regulations, price volatility, uncertain demand, fragmented landholdings, shortages of quality planting material, and limited access to insurance. Small and scattered project sizes, high transaction costs, and illiquidity further deter private investment.[121]

To address these challenges, a land use transition financing facility could be established, primarily funded by public capital. Target beneficiaries would include farmers and farmer-led enterprises implementing energy plantations, and natural farming projects. Grant funding would support early-stage activities such as land suitability assessments, procurement of high-quality seeds and planting material, and farmer training. Commercial capital would cover plantation establishment and maintenance. Given high insurance premiums for weather-related risks, the facility should also provide insurance and risk-sharing mechanisms to protect farmer incomes and investor capital.

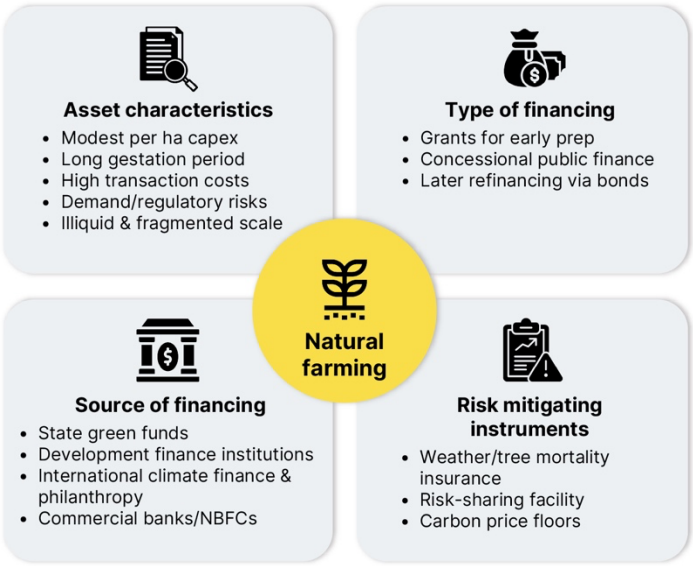
4.4.1.1 Financing mechanism

Energy plantation and natural farming projects combine relatively modest per-hectare capex with multi-year ramp up of cash flows, making them high gestation and risk sensitive in early phases. The Facility should therefore prioritise public and concessional sources for anchor funding, including state green funds (such as Birsa Harit Fund), national development finance, and international climate finance, supplemented by philanthropic grants for preparation and community capacity.

[121] Journal of Pharmacognosy and Phytochemistry. Agroforestry systems: Opportunities and challenges in India. *Sharma, P., Tiwari, P., Kamlesh V. & Singh, M*. January 2017. Pages 953-957.

Commercial banks and local NBFCs can participate progressively where credit guarantee and escrowed offtakes are in place, and where early carbon price revenues and insurance improve downside protection. Over time, portfolio scale and contracted revenues (pellet offtake to utilities/MSMEs, verified carbon issuances) should enable refinancing into longer tenor institutional capital and, potentially, pooled green bonds backed by project cash flows.

Figure 16: Financing framework for energy plantations and natural farming



Source: IEEFA

4.5 Mining of critical minerals

India is intensifying its focus on critical minerals, essential raw materials for low-carbon technologies, to bolster self-reliance and support its energy transition. In June 2023, the Ministry of Mines identified 30 critical minerals, including lithium, cobalt, nickel, and rare earth elements.[122] To boost investment, within months, the central government announced a 25% incentive for exploration projects.[123] It also amended laws to allow exclusive central auctions for 24 critical minerals, streamlining allocation and attracting public-private participation.

[122] Ministry of Mines. Critical minerals for India. June 2023. Page 3.
[123] PIB. Strengthening Critical Mineral Supply Chain. 27 November 2023.

Recognising the lack of domestic production for many of these minerals, the government is also considering investing in research collaborations. These would focus on developing extraction and beneficiation techniques to make processing more efficient and economically viable.[124]

Jharkhand, a major coal producer, has a strong mining ecosystem and extensive experience in mineral exploration. With one of India's largest critical minerals reserves, it is well-positioned to pioneer large-scale critical minerals mining.

This report uses some assumptions to project the capacity and cost of critical minerals mining in Jharkhand, such as:

1. Jharkhand holds reserves of more than 10 critical minerals essential for the energy transition, with five key minerals—copper, graphite, nickel, cobalt, and silica—identified.[125]
2. Estimates from the Indian Bureau of Mines (IBM) and National Mineral Exploration Trust (NMET) suggest significantly higher resource potential, including newly discovered lithium reserves that could support battery manufacturing. Jharkhand's production opportunities could expand as further exploration shifts more resources to proven reserves.
3. This report has cross-verified the critical mineral reserves with IBM and company filings.[126,127,128] Production is expected to primarily serve India's domestic demand for low-carbon assets such as solar PVs, wind energy, batteries and EVs.[129] Government mining plans, and private project reports/ filings, both domestic and global, form the basis of mine life, excavation capacity and capital expenditure estimates.[130,131] This report assumes cobalt mining will be a byproduct of copper and nickel mining.[132]

Table 17: Critical minerals mining potential and estimated capex in Jharkhand

Minerals	Proven Reserves (MT)	Total Capital Expenditure (Rs Crores)	Total Capex (US$ Million)
Copper	9	453	54
Graphite	20	2,292	273
Nickel	9	844	100
Silicon	136	5,635	670

Source: IEEFA

[124] PM India. National Critical Mineral Mission. 29 January 2025.
[125] CEED. Jharkhand's critical mineral reserves for energy transition. June 2024.
[126] IBM. Reserves of critical minerals. 2021.
[127] Hindustan Copper Ltd (HCL). . 2024.
[128] Vedanta. . 2024.
[129] CSEP. Projecting Critical Mineral Needs for India's Clean Energy Transition. June 2024.
[130] Ministry of Environment, Forest and Climate Change. Online Submission & Monitoring of Environmental & CRZ Clearances.
[131] For example, the Madhya Pradesh Pollution Control Board. Malanjkhand Copper Mine: Hindustan Copper Limited. 2011.
[132] Natural Resources Canada. Cobalt. 13 March 2025.

The estimates already reflects the higher costs of integrated mining and refining. Going forward, establishing such hubs within Jharkhand will be critical, as mining alone delivers limited value addition, while downstream processing anchors industrial supply chains. This will help the state position itself as a national hub for critical minerals directly contributing to India's supply chain resilience in clean energy and industrial sectors.

4.5.1 Financing mechanism and framework

Mining of critical minerals is heavily capital-intensive, requiring equipment and infrastructure, such as power generators, roads, and desalination plants. This, combined with a long-term investment horizon—16.5 years on average[133]—deters most investors.

In addition, the significant price volatility of critical minerals on the commodities market makes investors nervous. With the ongoing costs of labour, energy and supplies, which are ex-ante and incurred much before revenue realisation, there is no assurance of a profitable scenario.

The early stages of mining—discovery, exploration and development—are lengthy and highly risky for investors. There are also risks at all supply-chain stages: mining, processing and recycling. In addition, there are geopolitical risks, such as developing the necessary infrastructure to transport minerals from mines for processing, which is in the hands of government, and honouring offtake agreements. This challenging risk profile has created a systemic bias against private investment in crucial upstream and midstream projects.

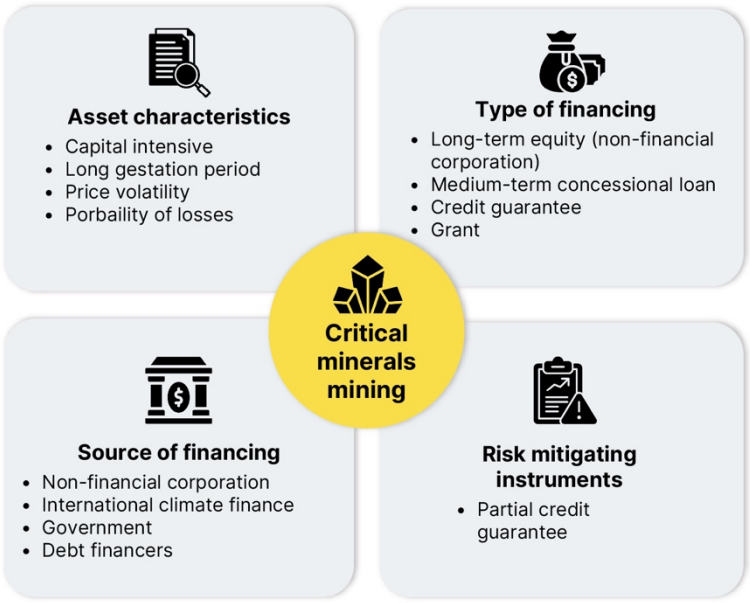
4.5.1.1 Financing mechanism

The primary capital sources are non-financial corporations with strong balance sheets and long investment cycles. In addition, grants and concessional debt can attract private capital. Grants are used along with private investment (by non-financial corporations) to facilitate the development of new projects and projects at the early and middle stages of development, where attracting external capital is challenging. In addition, concessional capital can attract private investment during the procession and extraction stage to mitigate the profitability concerns of mining projects.

A PCG is another way to attract commercial debt; a guarantee for multiple projects can reduce the risk of the guarantor. The government must also seek investment in public or shared infrastructure, such as roads and power generation plants. It can seek grants and concessional capital from MDBs and international climate finance mechanisms for mining critical minerals in the state for use only in clean transportation or renewable energy. MDBs can act as credit guarantors that can attract commercial debt financers to these projects.

[133] International Energy Agency (IEA). The Role of Critical Minerals in Clean Energy Transitions: Executive Summary. May 2021.

Figure 17: Financing framework for critical minerals mining



Source: IEEFA

5. Other economic diversification activities

The previous section outlined key sectors through which Jharkhand can diversify its economy during the transition away from fossil fuel dependence. These core sectors have the potential to generate substantial livelihood opportunities for workers directly and indirectly engaged in coal and related industries.

In addition, other sectors that already contribute to the state's economy and employment base could experience accelerated growth in the context of India's broader energy transition. They include agriculture and allied activities, green building, circular economy practices and IT and IT-enabled services (ITeS). With targeted, climate-focused policy support, these sectors could expand their economic footprint while creating new, sustainable livelihood opportunities.

5.1 Agriculture and allied activities

Agriculture remains a cornerstone of Jharkhand's economy, providing livelihoods for a large share of its population. The state's varied agroclimatic zones support diverse crops, including rice, maize, pulses, and horticultural produce such as tomatoes. Initiatives such as the Jharkhand Opportunities

for Harnessing Rural Growth (JOHAR)[134] project have strengthened community-led irrigation and market access by forming producer groups.

Targeted interventions have also transformed niche value chains into profitable enterprises. For example, Udyogini's Lac Value Chain initiative has revitalised lac cultivation, creating jobs in processing and marketing.[135] Additionally, Farmer Producer Organisations (FPOs), with support from the National Bank for Agriculture and Rural Development, have enabled collective marketing, improving farmers' bargaining power and returns.[136]

To build on these successes, Jharkhand can promote climate-resilient crops such as millets, pigeon peas and moringa.[137] This shift would improve productivity, diversify income sources, and enhance the long-term resilience of rural livelihoods in the face of climate change.[138]

According to a recent Jharkhand Just Transition Taskforce report on the macroeconomic analysis of diversification opportunities, low-carbon agriculture has the potential to generate over 217,000 additional jobs in the state in the coming decades.[139]

5.2 Green building activities

Green building initiatives offer immense employment potential across various sectors. With urbanisation and industrial growth on the rise, demand for sustainable infrastructure is increasing. Adopting eco-friendly construction methods will not only reduce energy consumption and environmental impact but also create green jobs in construction, renewable energy and sustainable material manufacturing.

Workers skilled in fly ash brick production, bamboo-based construction, solar panel installation and rainwater harvesting will be in demand, particularly in rural and semi-urban areas. Urban planners, policymakers and sustainability consultants will also be crucial in implementing and monitoring green building standards, creating skilled employment opportunities.

By investing in this sector, especially through skill development programmes, Jharkhand can establish a robust, sustainable employment ecosystem while positioning itself as a leader in India's green transition.

[134] World Bank. Leveraging Community Institutions to Support Agri-Business and Livelihoods in Jharkhand, India. March 2020.
[135] Udyogin. From Lac to Livelihoods: How Value Chain Interventions Transformed Jharkhand's Economy. August 2024.
[136] National Bank for Agriculture and Rural Development (NABARD). Collectivization of Agricultural Produce for enhancing Farmer's Income. 2022.
[137] India Water Portal. Jharkhand's agroforestry potential. March 2023.
[138] Economic Affairs. Pattern and trend in labour use in Indian agriculture: An analysis across major crops and states. *Raju S., Suresh A., Chand R., Chauhan S.* Volume 60/1. Pages 99-107. January 2015.
[139] UNDP. From Dependence to Diversification: Building a Future-Ready Workforce. September 2025

5.3 Circular economy

Enabling circular economy practices in Jharkhand can help ensure sustainable economic growth, promote social equity, and build resilient local employment for the future. Implementing a circular economy in Jharkhand would benefit the state by optimising resource use, minimising environmental impact, and creating new employment opportunities.

Circular practices[140] such as resource recovery from mining tailings, bioleaching techniques and closed-loop water management reduce waste and conserve resources. They also open up new roles for skilled workers in advanced mineral processing, environmental monitoring and technology maintenance. These activities require specialised knowledge and interdisciplinary collaboration among engineers, biologists and local communities, directly generating local jobs and sustainable livelihoods.

Beyond mining, circular initiatives in sectors such as textile and handloom have provided livelihoods to about 300,000 people in Jharkhand, comprising 200,000 farmers of tasar silk and 50,000 weavers, while the remainder are allied workers.[141] These farmers and weavers belong to tribal communities and marginalised groups. Expanding such sustainable models could generate thousands of green jobs, support MSMEs, and diversify the regional economy beyond traditional extractive industries.

5.4 IT and IT-enabled services

Jharkhand holds strong potential to emerge as a leading hub for IT and ITeS, supported by the development of IT parks and modern digital infrastructure. This growth can attract significant investment, stimulate entrepreneurship, and generate substantial direct employment in urban and semi-urban areas. It will also have a wide economic ripple effect, creating jobs in allied sectors such as logistics, facility management, security and transportation.

With targeted skill development and training, particularly for youth and women, the state can build a competitive workforce that meets evolving industry needs. Harnessed effectively, the IT and ITeS sector could play a transformative role in Jharkhand's economic landscape, driving inclusive growth and expanding employment opportunities across the region.

[140] International Journal for Multidisciplinary Research. Advancing Sustainable Resource Management in Jharkhand through Circular Economy Practices in Mining. *Kaushik R*. Volume 5/4. July-August 2023.
[141] United Nations Partnership for Action on Green Economy. Assessment of Green Jobs and Decent Work Opportunities in the Textile/Garment Sector in Jharkhand State, India. 2023. Page 9.

6. Steel sector decarbonisation in Jharkhand

Industrial decarbonisation is crucial for India's 2070 net-zero goal, as industries such as steel, cement, aluminium and petrochemicals contribute 20% of the nation's total emissions.[142] Effective strategies for decarbonising these industries must align with domestic and global climate goals. Through several key initiatives, India has been advancing industrial decarbonisation to meet its 2070 net-zero target.

The steel industry is particularly emissions-intensive, contributing 10-12% of India's greenhouse gas emissions.[143] As the world's second-largest crude steel producer, the country makes about 144Mtpa, contributing 2% to India's GDP.[144] Unlike plateaued demand in advanced economies, India's iron and steel sector is growing rapidly, both in output and emissions.

Jharkhand has a diverse industrial sector, which includes iron and steel, automobiles, chemicals, and handloom—key industrial hubs such as Jamshedpur, Bokaro and Ranchi host major industries.

The iron and steel industry forms the backbone of Jharkhand's industrial base, accounting for 20-25% of India's total steel production. With multiple ISP expansions in the pipeline, the state is poised to become the country's largest steel producer. Additionally, the state is also home to several MSME steel clusters, with several livelihoods dependent on the sector. Given this dominance, Jharkhand's industrial decarbonisation efforts will depend heavily on the transition of its steel sector.[145] Accordingly, this report models steel only, prioritised for its economic significance and MSME linkages.

Table 18: Steel sector capacities in Jharkhand, FY2024-25 (Mt)

	Coal-based direct reduced iron (DRI)	Blast furnace-basic oxygen furnace (BF-BOF)
Large-scale	1.0	18.4
Medium-scale	2.6	-
Total	**3.6**	**18.4**

Source: IEEFA

This report uses some assumptions to project the capacity and costs of steel decarbonisation in Jharkhand, such as:

[142] Shakti Sustainable Energy Foundation. Industrial Decarbonisation. June 2024.
[143] Reuters. India's SAIL ties up with BHP to reduce carbon emissions. 7 October 2024.
[144] Statista. Crude steel production in India FY 2012-2024. June 2025.
[145] Jharkhand Department of Industry. Jharkhand Industrial and Investment Promotion Policy 2021. July 2021. Page 2.

1. Drawing on the Ministry of Steel's sectoral decarbonisation roadmap and secondary research to define key decarbonisation levers for Jharkhand's BF-BOF and DRI capacities.[146,147,148] The three key levers for capex include energy efficiency, retrofits for green hydrogen, and installation of carbon capture and storage (CCS).[149] IEEFA assumes procurement of clean energy as a lever, and covers it as part of the renewable energy capacity projected for the state.
2. The state's steel capacity is expected to grow by 2.4Mtpa (or 13%) for BF-BOF and 4.4Mtpa for DRI, or more than double, by 2030, and increase at a steady annual rate of 5.3% thereafter.[150]
3. As existing plants reach the 40-year mark, most will be retired, with investment in new, low-carbon steelmaking technologies becoming more economically viable than retrofitting.[151,152,153] Additionally, some BF-BOF units may face early closure driven by policy measures such as carbon pricing.
4. All coal-based DRI units, including newly commissioned ones, are expected to be retired due to the absence of currently proven viable decarbonisation pathways.[154] This assumption may be revised in the future based on availability of feasible decarbonisation options and policy levers. In the interim, targeted investments in energy efficiency, renewable energy procurement, and material efficiency measures, such as pelletisation, will help reduce emissions from these operations.
5. A small portion of BF-BOF capacity will be retrofitted for green hydrogen and carbon capture, utilisation and storage (CCUS), while DRI units will not undergo retrofits. The new capacity will employ the best available technology, eliminating the need for energy efficiency investments but requiring green hydrogen retrofits and CCUS for BF-BOF units until these technologies become viable.
6. Cost estimates in this report reflect ISPs' strategy to procure, rather than produce, green hydrogen, with retrofits scheduled to begin in 2041 in line with the Ministry of Steel's roadmap, and CCUS deployment costs starting from 2051.[155]
7. While the Ministry of Steel identifies CCS (or CCUS) as critical to decarbonising the sector, IEEFA's research suggests CCS remains commercially unproven for large-scale steel applications.[156] CCS faces unresolved challenges around cost, scalability, infrastructure requirements and long-term storage risks. Given these uncertainties, CCS may ultimately

[146] Ministry of Steel. GSI report.
[147] CEEW. Evaluating Net-zero for the Indian Steel Industry. October 2023. Page 1.
[148] TERI. Achieving Green Steel: Roadmap to a Net-Zero Steel Sector in India. 2022. Pages 13-14.
[149] IEEFA research has shown that CCS looks increasingly unlikely to play a significant role in decarbonising the global steel sector.
[150] SAIL. Annual Report 2023-24. September 2024. Page 57
[151] IEEFA. Accelerating technology transition has begun to redraw the industry map. We can expect more in 2024. March 2024.
[152] IEEFA. Steel decarbonisation in India. September 2023.
[153] IEA. Age profile of global production capacity for the steel sector (blast furnaces and DRI furnaces). September 2020.
[154] CEEW. Decarbonising Coal-based Direct Reduced Iron Production. July 2024. Pages 16
[155] Ministry of Steel: Roadmap and action plan for green steel. September 2024.
[156] IEEFA. Steel CCUS update: Carbon capture technology looks ever less convincing. November 2024.

have a limited or no role in the sector's long-term decarbonisation pathway and should therefore be pursued with caution. As a result, CCS deployment in Jharkhand will require careful evaluation, pilot testing and strong safeguards to ensure technical viability and cost-effectiveness before committing to wide-scale adoption.

Table 19: Steel decarbonisation and estimated capex in Jharkhand

Technology	Capacity to be retrofitted	Timeline for retrofit	Capex (Rs billion)	Capex (US$M)
Energy efficiency	Existing	2031	161.1	1,916
CCS	Existing and new	2051	293.7	3,492
CCUS	Existing and new	2051	584.7	6,952
Green hydrogen	Existing and new	2041	20.5	243

Source: IEEFA

6.1 Financing mechanism and framework

The industrial sector, by structure, is capex-heavy. The higher costs of low-carbon industrial solutions exacerbate the upfront capital requirement. Capital expenditure on DRE, energy efficiency, CCUS and green hydrogen can potentially depress companies' profit margins, return on equity and cash flows in the near term. New debt could be expensive or unavailable, as it will increase financial leverage without a commensurate increase in profit or cash flows. A financing mechanism that enables the company to invest in necessary capex and R&D to reduce carbon emissions without adversely impacting the financial metrics will be key for steel decarbonisation.

For Jharkhand's large ISPs using BF-BOF technology, transition finance (bonds or loans) and SLBs or loans can help raise long-term capital to pursue less carbon-intensive steel production. Using proceeds of transition financing is more flexible than green finance, and thus creates more investment and decarbonisation options.

Companies can raise capital at a corporate level, which allows them to finance the business to optimise profitability and reduce carbon emissions. It is also economical for large companies to raise transition finance at the corporate level instead of at the project level. The financiers can set terms and conditions, with financing linked to specific outcomes (for SLBs) to create accountability and transparency. For instance, the financier may set a long-term target of reducing GHG emissions from the borrower's business operation. Concessional long-term debt to decarbonise is another way to incentivise companies to invest in low-carbon solutions.

6.1.1 Financing strategy: Steel ISPs

The source of equity capital will be corporations. However, companies with strong balance sheets can raise equity in the secondary market to start new projects (e.g., steel facilities with electric blast furnaces and green hydrogen). Commercial banks can provide debt to the fund but need a substantial credit guarantee as the perceived and real risks are very high in steel decarbonisation

projects. Domestic public financial institutions, MDBs and bilateral financial institutions can provide concessional debt capital.

Figure 18: Financing framework for steel ISPs

Source: IEEFA Analysis

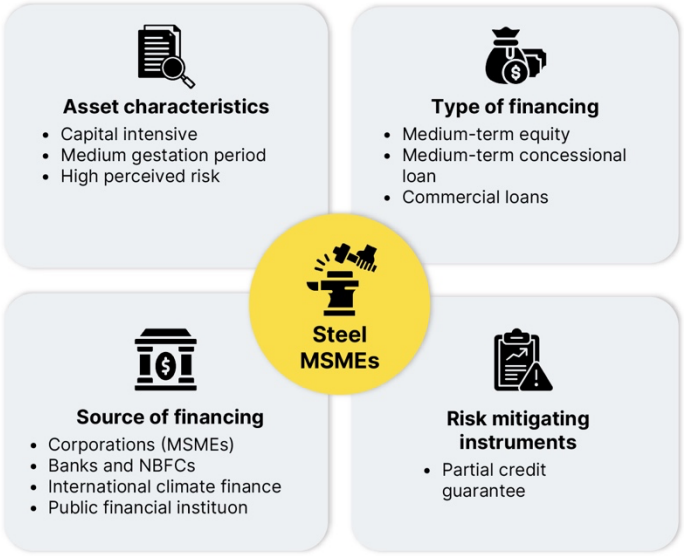
6.1.2 Financing strategy and future actions: MSMEs

Energy efficiency is the only feasible decarbonisation lever for small and medium-sized enterprises using coal-based DRI steel production. These enterprises usually deploy their equity to grow their businesses instead of energy efficiency, even though energy saving improves their return on investment in the medium to long term. Instead, they seek external debt to invest in energy efficiency as it does not help to grow or stabilise the business operations. However, they struggle to secure loans from banks and NBFCs—the two primary sources of debt for these enterprises. Limited financial track record, lack of financial transparency and high perceived financial risk discourage mainstream lenders from providing capital to medium-sized enterprises.

From the creditor's perspective, the need for collateral is much more valuable than the cash-flow generated from the project; the high cost of borrowing and the short-term availability of debt discourage them from borrowing.

Domestic public financial institutions, MDBs and bilateral financial institutions can provide concessional debt through commercial banks and NBFCs; the latter can pass on the benefits of concessional debt capital to these enterprises (borrowers), but they need a substantial credit guarantee. Domestic public financial institutions, MDBs and bilateral financial institutions can offer PCGs to banks and NBFCs to reduce the riskiness, real or perceived, of these loans.

Figure 19: Financing framework for steel MSMEs



Source: IEEFA Analysis

7. Ensuring a Just Transition at the coalface

The transition from coalmining and TPPs to a low-carbon economy will profoundly impact workers and communities reliant on the coal ecosystem. It will not only reshape energy production but also alter the livelihoods of those directly or indirectly dependent on coal-related activities.

One key aspect of diversification is the creation of new jobs and economic activities. As the state moves towards low-carbon sectors, it is imperative the existing workforce adapts to new roles and technologies. This transition necessitates significant skill changes, particularly for workers in traditional sectors such as coal. Therefore, reskilling and upskilling are essential to mitigate the impacts of this shift. Studies globally have shown that semi-skilled workers in industries most affected by the energy transition are open to reskilling within their current roles.[157] However, the situation in Jharkhand might differ due to Coal India Limited, the largest coalmining employer, offering attractive compensation and benefits.[158]

Another key aspect is providing compensation for formal and informal workers, and transition support for livelihoods dependent on the coal economy, such as washery workers, traders,

[157] Gallagher. Why a Just Transition Matters. December 2024.
[158] Insights gathered through stakeholder consultations with civil society organisations (CSOs) working in Jharkhand.

transporters and even local business owners, such as tea sellers and grocers. One-time compensation ensures a sufficient economic buffer for these individuals as they find new livelihoods.

7.1 Labour support cost

This report estimates the labour support costs for formal, informal and induced workers based on the following assumptions using national employment data, research reports and organisational annual reports:

1. **Job and livelihood loss estimation:** Each year, as coalmines and TPPs are phased out, the number of lost jobs and livelihoods is estimated based on secondary literature.[159] These estimates differentiate between business-as-usual (BAU) closures, which follow the asset's natural lifespan, and accelerated closures, which occur before the expected end of life.
2. **Reskilling and upskilling costs:** For BAU and accelerated closures, the costs of reskilling and upskilling formal and informal employees are calculated based on data from India's reskilling programmes for green jobs, and validated through expert consultations.[160,161]
3. **Support for induced livelihoods:** Transition support costs are estimated for individuals who lose livelihoods due to loss of economic activity from the closure of coal assets. This compensation covers the interim period before new economic activities are established in the area, and has been assumed to be provided for two years.[162]
4. **Compensation for accelerated closures:** Accelerated closures require additional financial support. For formal employees, this includes voluntary retirement schemes (VRS) for a proportion of the workforce, and compensation for those who do not opt for VRS. Informal employees receive compensation payments only.

Table 20: Just Transition support provided for formal, informal and induced jobs

Applicability	Reskilling	VRS (retirement)	Compensation	Transition support
Coalmine workers				
Formal	✓	✓	✓	✗
Informal	✓	✗	✓	✗
Induced	✓	✗	✗	✓
TPP workers				
Formal	✓	✓	✓	✗
Informal	✓	✗	✓	✗
Induced	✓	✗	✗	✓

Source: IEEFA

IEEFA estimates around Rs710 billion (US$8.4 billion) would be needed to support labour during coalmine closure, this would mainly include reskilling and transition support costs. Similarly, about

[159] For example, International Forum for Environment, Sustainability and Technology. Just Transition Costs and Cost Factors: A Decomposition Study. March 2023.
[160] India Business Trade. India's Skill Upgrade Package: A Blueprint for a Developed Nation? 27 July 2024.
[161] Keka. Minimum Wages in Jharkhand. January 2024.
[162] Based on stakeholder consultations with CSOs working in Jharkhand.

Rs55.6 billion (US$661 million) will be needed for labour support as TPPs close, mostly to reskill workers.

Table 21: Labour support cost in Jharkhand 2030-2070

Labor support	Total Capital Expenditure (Rs Crores)	Total Capital Expenditure (US$ Million)
Labor support- Coal mine	71,047	8,447
Labor support- TPP	5,557	661
Total Labor support	**76,604**	**9,108**

Source: IEEFA

7.2 Community resilience cost

Beyond labour support, ensuring community resilience as coalmines and TPPs are phased out will require significant investment. Coal companies and associated entities have historically contributed to local communities through corporate social responsibility (CSR) funds. Additionally, District Mineral Foundation Trust (DMFT) funds, financed by coalmining revenue, are directed at districts affected by mining operations. However, as these coal assets close, these vital contributions will diminish, leaving communities vulnerable. Replacing these investments is critical to mitigate the socio-economic impacts of the transition.

This report estimates the investment needed to sustain community resilience based on the following assumptions and methodology:

1. **Replacement of contributions:** As coal assets close, their funding for community resilience must be replaced. This includes maintaining and enhancing social infrastructure, investments in physical infrastructure, and livelihood support in affected regions.
2. **Social infrastructure costs:** The costs of essential services such as healthcare, education, drinking water and electricity access are calculated based on historical DMFT spending.[163,164] Unit costs of retired capacity are estimated by analysing per capita expenditures in districts with coal operations, proportioned across key services based on data from Coal India subsidiaries in Jharkhand.
3. **Annual cost estimates:** For each year, as coal capacity retires, we calculate the corresponding social infrastructure spending required to sustain these services.
4. **Infrastructure and livelihood investments:** In addition to social infrastructure, investments in physical infrastructure and livelihoods are estimated using historical spending trends and linked to the scale of capacity being retired.[165]

[163] CSR Journal. Top CSR Projects in Jharkhand. September 2022.
[164] Ministry of Mines. Jharkhand DMF. November 2024.
[165] Ministry of Mines. Jharkhand DMF. November 2024.

Table 22: Community resilience cost in Jharkhand 2030-2070

Community resilience	Total cost (Rs billion)	Total cost (US$M)
Maintaining and enhancing social infrastructure	160.7	1,910
Infrastructure investment	90.4	1,074
Livelihood investment	37.4	445
Total	**288.4**	**3,429**

Source: IEEFA

7.3 Financing policy

Financing initiatives for labour support and community resilience primarily rely on public resources, as these activities typically do not generate sufficient returns to attract private sector participation. However, limited private investment in skilling may occur if companies diversify or begin operations in coalmine or TPPs areas. Beyond this, the bulk of funding must come from public sources. Key funding avenues include:

1. **Coalmining and TPP companies:** The coalmine closure framework does not account for the associated social costs, and there are no closure guidelines for TPPs in India. Integrating social costs into this framework could encourage coalmines and TPPs to adopt social initiatives as part of their operations.
2. **District mineral funds:** The DMFT and District mineral fund (DMF) are significant funding sources for labour support and community resilience. In FY2023-24, Rs24 billion (US$283 million) was collected within the state through the DMF. Projections suggest substantial DMF collections will continue until 2040, providing a steady funding stream for resilience-building initiatives. Developing a robust strategy for better utilisation of DMF allocations can help channel these resources effectively towards Just Transition goals.
3. **State government budget:** State funding is crucial for labour support and community resilience initiatives. To enhance its effectiveness, Jharkhand should conduct a comprehensive green budgeting exercise. This involves analysing public expenditures and revenues to assess their contribution to environmental and sustainability goals. Such an approach allows for strategically reallocating resources to Just Transition activities such as labour retraining and community resilience. It also improves the state's capacity to secure external funding from international donors, climate funds and multilateral agencies.
4. **Other sources:** In addition to public funds, several alternative sources of financing can be leveraged to support Just Transition activities. Philanthropic grants from foundations prioritising climate action and social equity can provide flexible funding for labour retraining, community development and resilience-building initiatives. Concessional loans from institutions such as the World Bank, Asian Development Bank and Green Climate Fund can address financing gaps, particularly in large-scale infrastructure and training programmes. Contributions from the private sector via CSR initiatives are crucial for community welfare and skill development.

7.3.1 Just Transition fund

Establishing a dedicated Just Transition Fund is essential for consolidating and effectively managing diverse funding sources to support transition-related activities. This fund would enable the development of long-term, strategic financing plans tailored to the unique challenges and opportunities of a Just Transition. It can serve as a centralised mechanism to channel public resources into targeted initiatives, ensuring labour retraining, community resilience and sustainable infrastructure projects receive consistent and adequate funding.

A well-designed Just Transition Fund can act as a bridge to mobilise private capital by leveraging public investments and existing infrastructure. It provides transparency, accountability and a structured framework for fund allocation, attracting investors with environmental, social and governance (ESG) objectives. The fund also promotes partnerships among public, private and international stakeholders, fostering a collaborative approach to achieving Just Transition goals.

8. Supporting the state with revenue substitution

As Jharkhand phases out coal assets, primarily coal mining, their contribution to the state's own revenue, which accrues in the form of royalty and state GST, will fall. As stated earlier in this report, coal contributed 17% of the state's own revenue in FY2023-24.

Diversifying the state's economy into new low-carbon sectors will add to its GDP, contributing materially towards Jharkhand's own revenues. Thus, the transition will more than compensate for the state's lost coal-based revenues (Table 22).

Table 23: Revenue substitution for Jharkhand (2026-2070)

Revenue substitution	Total Revenue loss and substitution (Rs Crores)	Total Revenue loss and substitution (US$ Million)
Revenue loss due to coal asset closure (A)	(4,15,777)	(49,433)
Revenue from low carbon manufacturing setup (B)	10,68,680	1,27,058
Revenue from Critical minerals mining (C)	23,801	2,830
Net Revenue substitution (Excess/(deficit)) (B+C-A)	**6,76,703**	**80,455**

Source: IEEFA

By transitioning from a fossil fuel-dominated economy to new, low-carbon sectors, IEEFA estimates Jharkhand will be able to more than offset the loss of coal-based revenues. Further, the resultant revenue boost will significantly increase corporate tax and duties to the central government, and Jharkhand's share of this revenue will reinforce its transition efforts.

9. Policy levers required for a Just Transition

For a successful Just Transition in Jharkhand, the state needs to implement policy changes to help garner financing support for low-carbon sectors. Additionally, it will need to collaborate with MDBs and focus on policies to develop the workforce's capacity to succeed in the new, low-carbon economy. This section details the specific policy actions the state needs to implement.

9.1 Developing a robust financial policy

Attracting capital for low-carbon technologies faces several financial hurdles, especially in developing economies such as India. These challenges fall under three categories: cost of financing, access to finance, and volume of finance. As most low-carbon technologies are capital-intensive, the cost of finance determines the viability and attractiveness of these technologies. The high cost of financing discourages companies from setting up and scaling up low-carbon technology investments. For certain low-carbon technologies (e.g. DRE), access to finance also remains a challenge for project developers. Even if capital is flowing to these technologies, the volume of finance is significantly lower than the requirements. The Jharkhand government can intervene to address these challenges through targeted financial policies and programmes.

A robust policy framework is vital to guide and reassure stakeholders. Governments need to develop and implement co-ordinated policies for green technologies such as DRE systems, solar farms and energy storage solutions. Regular stakeholder engagement is necessary to keep these policies relevant and responsive to new challenges and opportunities.

9.1.1 Financing support for green industries

Since most green technologies require significant capital, securing low-cost debt is essential to attract investors. The challenge of accessing affordable debt is a barrier to accelerating the green transition. The central government has successfully used interest subvention to lower interest rates for priority sectors. Similarly, the Jharkhand government could help local companies secure concessional debt from domestic public financial institutions.

Furthermore, certain green technologies, such as BESS and biomass, require substantial initial capex to become commercially viable for private sector involvement. Governments can facilitate this by providing grants or capital subsidies. The central government and international institutions and foundations already offer financial support for low-carbon technologies. The Jharkhand government should assist local companies to access these grants to foster investment in the state.

Lastly, the Jharkhand government can cover a portion of employees' provident fund contributions, reimburse stamp duty and waive registration fees for companies starting greenfield projects in low-carbon industries.

9.1.2 Opening a window for low-carbon investment

The Jharkhand government can position the state as a prime location for low-carbon technology investments. By establishing a green sector cell, the government can facilitate the establishment of low-carbon facilities and swiftly address investor concerns. Additionally, organising events (e.g. a green investment summit) to highlight investment opportunities could attract investors to explore potential projects and partnerships in the state.

One of the cell's key tasks should be to ensure land availability for renewable energy generation and other economic diversification sectors. The government should streamline land allocation processes to make it easier for developers to find suitable sites. This could involve clarifying land-use policies, designating green zones for such projects and expediting approvals for projects aligned with sustainability goals.

9.2 Collaborating with MDBs

States can work with MDBs to design and develop a pipeline of bankable projects that can attract funding from both MDBs and private financial institutions. MDBs bring deep expertise in structuring green and climate-resilient projects, along with the ability to strengthen state capacity through policy and regulatory design, institutional development and knowledge sharing.

By engaging with MDBs, Jharkhand can access concessional debt and guarantees, leveraging these to attract private investment. For instance, Goa's partnership with the World Bank to establish a blended finance facility, using concessional debt to mobilise private capital for low-carbon and resilience projects, offers a strong precedent.[166] Jharkhand could adopt a similar model, forging strategic partnerships with MDBs to expand investment flows. This can be supported by hosting green investment summits and roadshows, where MDBs such as the World Bank convene other international financiers, public institutions, corporations and private investors to showcase the state's pipeline of green sector opportunities.

9.3 Capacity building

Capacity building is essential for a transition to a sustainable, low-carbon economy. Collaborating with leading Indian Institutes of Technology, National Institutes of Technology, Industrial Training Institutes and the Skill Council for Green Jobs would help equip local youth with the necessary skills in green technologies. These partnerships would develop specialised curricula and short- and long-term training programmes tailored to renewable energy, energy efficiency, clean transportation and energy storage.

[166] PIB. Government of Goa and Power Finance Corporation come together to pioneer subnational Blended Finance Facility for Climate Action. 20 February 2024.

Grants are crucial in this initiative to fund the development of advanced curricula and practical training in areas such as solar PV installation and energy auditing. Emphasising technical and entrepreneurial skills prepares participants for roles in the green workforce and as future innovators.

Additionally, increasing financial institutions' capacity to fund green projects is vital. Collaborations with state-level banks to offer financial products suited for small-scale projects and DREs, along with training bankers about the specifics of green technologies, can encourage them to finance these sectors.

9.4 Developing an ecosystem for corporates and investors

Corporations are key to strengthening the green technology ecosystem. Encouraging partnerships within the industry can help create efficient supply chains. For instance, linking renewable energy developers with local manufacturers of components such as solar panels or wind turbines enhances local production capacities and reduces import dependency. These collaborations can lead to cost savings, improved product quality and streamlined logistics.

Investor engagement is equally important for expanding green technology deployment. Establishing platforms that connect investors with corporations can direct necessary financial resources into green projects. Providing investors with detailed project pipelines and risk-mitigation strategies can increase their confidence. Additionally, government-backed guarantees or subsidies can attract further private investment.

10. Roadmap for implementation

The green economic transformation holds many challenges for actors in the system. Hence, effectively driving systemic change needs an integrated approach for policy and regulatory cohesiveness and embed collaboration across the public and private sectors. A roadmap will be a comprehensive strategy that will act as a blueprint for private and public actors. The roadmap will identify the steps needed to make transformational changes in the system that will enable stakeholders to make informed decisions. The first step for the Jharkhand government will be to announce a roadmap to transition to a green economic structure, which will send a signal to stakeholders, particularly investors, on the state's intention for a green economic transformation. Outlined below are the short-, medium- and long-term action plans for state government, serving as a strategic pathway toward green economic transformation.

Table 24: Action plan for Just Transition in Jharkhand

Green components	Short-term (2026-30)	Medium-term (2030-2035)	Long-term (post 2035)
Asset closure			
Economic diversification (RE and manufacturing)			
Green hydrogen production			
Critical minerals mining			

Steel decarbonisation			
Just Transition			

Source: IEEFA

10.1 Short-term priorities (to 2030)

Short-term policy recommendations focus on industries near commercialisation, which the Jharkhand government should prioritise within the next three to five years due to their significant growth potential. While renewable energy sources such as solar and wind are already commercialised, BESS, EVs and battery manufacturing are close to commercialisation. Investment in grid and transmission enhancements is crucial to support the expansion of solar and wind energy.

Additionally, the steel industry, which is integral to Jharkhand's economic growth, needs urgent decarbonisation strategies. Early planning is essential despite high-carbon asset closures not expected until after 2040. The Just Transition process, including reskilling for green industries and rehabilitating workers from high-carbon sectors, should also start in the short term due to its extended timeframe to yield results.

10.2 Medium-term initiatives (2031-35)

The medium-term policy suggestions highlight areas to target within the next five to 10 years to help India achieve its net-zero targets. During this period, the Jharkhand government should prioritise developing a green hydrogen ecosystem, which is expected to reach commercial maturity in five to 10 years.[167] Implementing strategies now will align with the technology's potential to help decarbonise the state's steel sector. Additionally, the state should focus on expanding renewable energy generation and manufacturing low-carbon assets throughout this phase.

10.3 Long-term (post 2035)

Beyond 2035, coalmining and TPPs closures will be key. While TPPs will continue to operate until 2040, the Jharkhand government should initiate a transition plan to prepare for the eventual closure of industries critical to the state.

11. Conclusion

Jharkhand's coal economy has played a crucial role in powering industries across the country, generating revenues for the state, and providing direct and indirect employment to millions. Coalmining has been a significant source of income for the state government through royalties and

[167] MNRE/EY. India's Green Hydrogen Revolution – An Ambitious Approach. May 2024. Page 31

taxes, while also supporting ancillary industries such as steel, transport, equipment manufacturing and local markets.

To build a resilient and sustainable future as the coal economy phases down, Jharkhand must actively diversify its economy by investing in low-carbon assets. This report has identified key sectors for diversification that hold significant potential for the state's economy. These sectors include renewable energy, green hydrogen, energy storage solutions and sustainable, low-carbon manufacturing industries, such as BESS, EVs and solar PV modules, and energy plantation and natural farming. Additionally, Jharkhand's rich mineral resources can be leveraged for a Just Transition by expanding into critical minerals required for clean energy technologies.

The transition should also be equitable to livelihoods and communities directly or indirectly dependent on the state's fossil fuel economy. This report identifies key interventions, both financial (such as transition support compensation) and non-financial (such as skill development) that are essential for an equitable transition for direct, indirect and induced employment within coal assets.

While India's coalmining economy may peak in the late 2040s, careful planning to open Jharkhand's economy to other sectors and identifying key financial and capacity-building needs will ensure the transition is orderly and avoids any shock to the state budget. This report identifies the key policy levers, collaborations and ecosystem development activities that will aid the transition strategy. It also presents a plan that emphasises priority work areas in the short, medium and long term.

Mobilising financing for the energy transition sectors, including funding Just Transition activities, should be a priority for Jharkhand. To raise the required quantum of capital, the state will need to tap capital providers with varied risk-return profiles and investment horizons. This will also require derisking several investments through policy support at state and central levels. The sustainable finance framework proposed in this report can help assess the right financial intervention and derisking required to mobilise capital.

Jharkhand stands at an important crossroads in India's ensuing energy transition. A well-calibrated strategy for a Just Transition today will help the state not just diversify but also grow its economy multifold in the coming decades. Stakeholders, led by the state government, must proactively make concerted efforts to work on this strategy and this future opportunity.

12. Annexure

12. 1 The Sustainable Finance Framework

Details of the capital providers IEEFA considers to assess the financing of coal asset closures, economic diversification and Just Transition activities in Jharkhand are in the table below.

Table 25: Capital providers suited for financing Jharkhand's energy transition

Provider	Category	Type of capital	Risk profile	Duration
Banks	Commercial financier	Short- to medium-duration debt	Low to moderate	1-12 years
NBFCs	Commercial financier	Short to medium-duration debt, often require collateral	Moderate	1-15 years
Pension and insurance funds	Public and private investors	Investments in long-term bonds and primary/ secondary equity	Risk-averse	5-30+ years
Mutual funds	Pooled private investor	Investments in bond and equity and exchange-traded funds (ETFs)	Low to high	1-10 years
Private equity	High-risk investor	Equity and risky debt financing at a higher interest rate, alternative investment funds	High	5-10 years
Venture capital	High-risk investor	Early-stage equity financing, high-risk high return	High	3-7 years
MDBs and climate finance mechanisms (Green Climate Fund)	International financier	Long-term concessional loans, grants, equity financing, guarantees	Low to moderate	10-30+ years
Domestic development banks (NABARD, SIDBI)	Public sector financier	Long-term, often subsidised loans, credit guarantees, microfinance	Low to moderate	5-20 years
Public sector (PFC, REC, IREDA)	Public sector financier	Long-term debt, project financing	Low to moderate	10-20 years
Government grants and subsidies	Government	Grants, subsidies, tax incentives	Low	na
Development agencies	Donors and DFIs	Grants, concessional loans, technical assistance	Low	5-30 years
Energy companies	Sector-specific investor	Project finance, direct project investments	Moderate to high	5-20 years

Source: IEEFA

12.2 Coalmine closure

IEEFA's estimations of capacity expansions for coalmining in Jharkhand are in the table below.

Table 26: Expected capacity additions for coalmining in Jharkhand

Period	Area (ha)	Capacity (Mtpa)
2026-2030	29,812	160.2
2031-2035	8,029	43.1
2036-2040	8,855	47.6
2041-2045	9,766	52.5
2046-2047	4,182	22.5
Total	**60,643**	**325.9**

Sources: Ministry of Coal, IEEFA

12.3 Economic diversification of Jharkhand

12.3.1 Low-carbon power generation and storage assets

Cumulative capacity addition projections for the state's renewable energy and storage assets are given in the following figures.

Figure 20: Cumulative renewable energy capacity projection, MW (2026-2070)

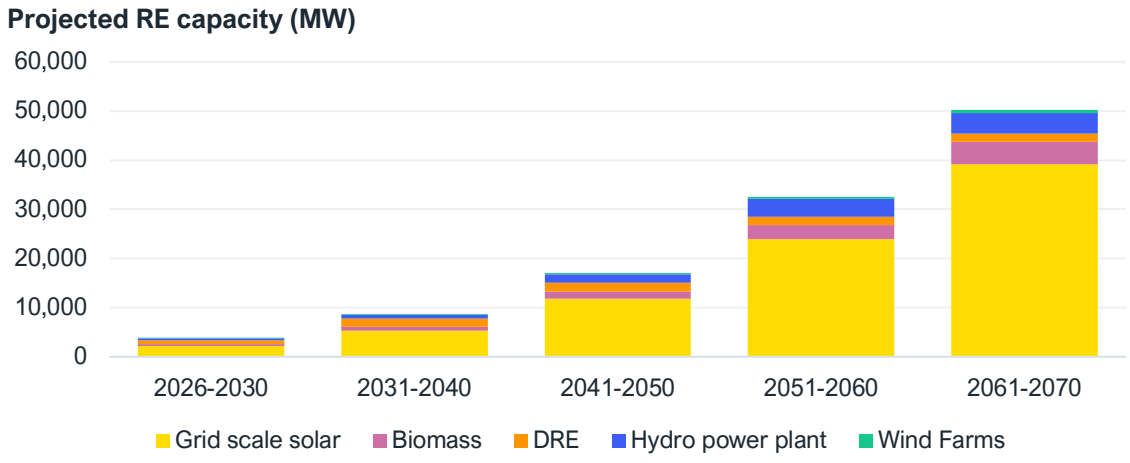
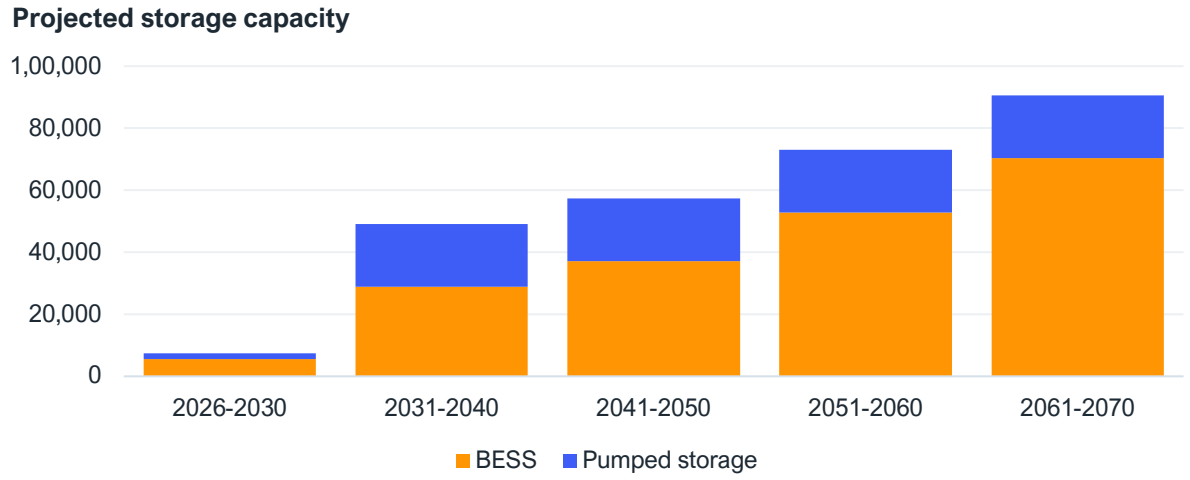


Figure 21: Cumulative storage capacity projection, MW (2026-2070)



12.3.2 Mining of critical minerals essential for the energy transition

Table 27: India's annual mineral requirements for solar PVs, wind turbines and BESS

Minerals (t)	2026	2027	2030	2032	2037	2042	2047
Cobalt	49	147	3,878	786	2,667	3,370	5,914
Copper	1,21,160	1,64,232	3,75,091	1,40,454	2,30,649	2,73,396	3,68,143
Graphite	1,814	5,405	1,42,892	28,966	98,259	1,24,153	2,17,884
Nickel	3,057	6,663	17,492	6,008	16,349	17,071	26,203
Silicon	91,330	1,12,789	2,13,051	91,596	1,29,331	1,58,413	1,97,077

Source: CSEP

12. 4 Industrial decarbonisation in Jharkhand

The table below provides details on mapping each steel manufacturing technology with its decarbonisation lever.

Table 28: Decarbonisation levers based on steel manufacturing technology

Applicability	Energy efficiency	CCUS	Green hydrogen
Coal-based DRI			
Medium-scale	✓	✓	✓
Large-scale	✓	✗	✗
BF-BOF			
Medium-scale	✓	✓	✓
Large-scale	✓	✓	✓

Source: IEEFA

12.5 Supporting Jharkhand with revenue substitution

This report focuses only on the revenue loss directly affecting the state treasury. Hence, we do not consider income taxes and the central government's portion of taxes. The estimates for losses and revenue substitution are based on the following assumptions:

1. Jharkhand's state revenue is projected to grow by 12.4% (based on the 10-year average of FY2013-FY2023).[168]
- The contribution from coal is based on average taxes and royalties paid by the companies operating in the state.[169,170,171]
2. When coalmines close, revenue losses are offset by the revenue the state government would make from economic diversification activities.
3. Revenue from economic diversification activities is calculated based on taxes paid by enterprises engaged in similar activities.

Table 29: Projected revenue substitution for Jharkhand (2026-2070)

Revenue substitution	Total Revenue loss and substitution (Rs billion)	Total Revenue loss and substitution (US$ Million)
Actual revenue from coal mining factoring the closure of mines- royalty	(3,620)	(43,047)
Actual revenue from coal mining factoring the closure of mines- SGST	(537)	(6,386)
Revenue loss due to coal asset closure (A)	**(4,158)**	**(49,433)**
Revenue from EV manufacturing- SGST	904	10,752
Revenue from Battery manufacturing- SGST	2,290	27,230
Revenue from Solar module manufacturing- SGST	6,982	83,011
Revenue from green hydrogen manufacturing- SGST	510	6,065
Revenue from low carbon manufacturing setup (B)	**10,687**	**1,27,058**
Revenue from Critical Mineral Mining-Royalty	134.6	1,600

[168] Comptroller and Auditor General of India. Finances of the State Government – Chapter 1. Jharkhand. 2014; Audit Report. Jharkhand. August 2024.
[169] Central Coalfields Ltd. Annual Reports. FY 2023-24
[170] Bharat Coking Coal Ltd. Annual reports. FY 2023-24
[171] Eastern Coalfields Ltd. Annual reports. FY 2023-24

Revenue from Critical Mineral Mining - SGST	103.4	1,230
Revenue from critical minerals mining (C)	**238.0**	**2,830**
Net Revenue substitution (Excess/(deficit)) (B+C-A)	**6,767.0**	**80,455**

Source: IEEFA. Note: The estimate for loss of revenue to the state from the phase-down of coal assets only considers own revenues for the state, including royalties and state GST. Other taxes arising from the coal economy, such as CGST, IGST and corporate tax, which the state receives through redistribution from the central government, are not considered. Similarly, we have not considered the same taxes arising from economic diversification activities (where applicable).

About the Task Force

The Government of Jharkhand has established a Task Force on Sustainable Just Transition to support national climate goals of achieving net-zero emissions by 2070, along with addressing associated socio-economic issues. The Task Force aims to provide key recommendations to the Government of Jharkhand on the sustainable transition for a future-ready Jharkhand by identifying innovative pathways for transitioning to a non-fossil fuel-based ecosystem, assessing the impact on the economy, workers and communities, identifying opportunities in green sectors, and recommending policy interventions.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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