# India's State-Owned Energy Enterprises, 2020–2050:

## Identifying evidence-based diversification strategies

**IISD REPORT**

IISD International Institute for Sustainable Development

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# Executive Summary

India has positioned itself as a strong advocate of climate action among emerging economies. It has shown leadership in scaling up renewable energy, with a target of installing 500 GW of non-fossil power by 2030 and spearheading the International Solar Alliance. In 2021, at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change, India pledged to reach net-zero emissions by 2070 and agreed to a phase-down of unabated coal power as a part of the Glasgow Climate Pact. This commitment has kickstarted an examination of possible decarbonization pathways for fossil-dependent enterprises. These decarbonization objectives and the scaling-up of clean energy are intertwined, and together they present both risks and opportunities.

State-owned enterprises (SOEs), known in India as public sector undertakings (PSUs), dominate the country's energy system. Several PSUs are among the most profitable firms in the country, and they have played a major role historically in investing in underdeveloped regions. As major employers in the conventional energy sector, they also have a clear role to play in ensuring a just transition for workers and communities over the next decades. This requires an evidence-based approach to planning the SOEs of the future.

At the time of writing, the Government of India had not elaborated formal targets or a timeline for a coal phase-down. The updated nationally determined contribution to the United Nations Framework Convention on Climate Change does not mention this issue (Government of India, 2022). As such, the best reference for its formal position is the intended nationally determined contribution submitted in 2015, which states that coal is vital "to secure reliable, adequate and affordable supply of electricity" (Government of India, 2015). While acknowledging this official position, we hold that it is important for coal-dependent SOEs to react to the possibility that ambition may well change in future years. This reflects many factors, including the importance of reducing coal consumption to achieve climate targets, the fact that a ratcheting up of policy ambition is built into global climate negotiations, and the rapidly improving economics of clean energy.

Our study builds on the foundations of Köberle et al. (2020) and expands its research design (see Figure ES1). Our aim is to set out an evidence-based approach on how firms can identify business risks while also illustrating the "opportunity" in transition—how SOEs can mitigate risk by helping to deliver a share of India's clean energy targets. We demonstrate this approach by showing how it can be applied to three central-level PSUs that play fundamental roles in the coal-to-power value chain: Coal India Limited (CIL), the largest national coal miner; NTPC, the largest thermal power producer; and Indian Railways (IR), the primary transporter of coal across the country. We use the green economy model (GEM) to identify production and consumption trends for coal and renewable energy between 2020 and 2050. For scenarios, two pathways have been developed, aligned with estimates published by the International Energy Agency's (IEA) *India Energy Outlook 2021:* a Business-As-Usual (BAU) case and an Aspirational scenario that is largely consistent with achieving net-zero. This approach is intended to capture the "risk spectrum" of future uncertainty for coal-dependent firms at the current time, falling between low and high ambition. The model outputs are then used in tandem with public financial disclosures to estimate the cash flow at risk for CIL, IR, and NTPC. This is the difference in estimated cash flow between the BAU and Aspirational pathways. We go further, identifying diversification strategies that can be used to mitigate these risks and quantifying their positive cash flow benefits where possible.

**Figure ES1.** Research design

| Energy model | Financial analysis | Diversification strategies |
|---|---|---|
| Green economy model (GEM) | Annual report, financial statements, public disclosure | Expert consultations, annual reports, stated ambitions |
| Coal and renewable energy production and consumption trends, 2020–2050 | Cash flow at risk (CFaR) assessment | Opportunities for diversification |

The key findings, summarized in Table ES1, indicate that an approach like this can effectively demonstrate how all three businesses are prone to financial risks. These risks add up over time and hence, there is a need for immediate action. The approach can also identify key takeaways for each of the PSUs and their nodal ministries. As a result, six major cross-cutting recommendations for the PSUs are listed below. The relevance of this approach extends beyond the three firms analyzed to include other fossil fuel-dependent PSUs in India and similar energy SOEs in emerging economies.

1. **Create a net-zero roadmap:** Meeting near-term demands, such as resolving coal shortages or keeping energy prices in check, is critical. However, decisions made now can have long-term consequences. A roadmap with interim targets for the firm, developed in consultation with relevant stakeholders, can become a guide for future decisions.
2. **Develop in-house estimates on business risks in the energy transition:** This analysis is based on simplified assumptions and publicly available information. However, firms are best placed to assess their own risks and opportunities, using this approach in combination with their own more precise internal data.
3. **Identify new clean energy business opportunities:** As markets emerge, new value chains are created. With their existing fossil fuel-based revenue streams and ability to raise capital at favourable rates, PSUs are well placed to become early adopters of clean energy.
4. **Set clean energy targets in proportion to existing risks:** Following the above two points, ambitions to develop clean energy businesses must be designed to match the potential scale and speed of the energy transition to comprehensively mitigate downside risks. This mitigation includes setting investment targets for clean energy and periodically revising ambition.
5. **Build strategic partnerships:** Develop partnerships to exchange expertise and invest in research and development. Inter-PSU contracts, such as purchase arrangements, can bring in new investors. Partnerships and acquisitions with smaller, innovative private firms can also help build internal capacity in new and emerging clean energy technologies.
6. **Make ambitions for the transition public:** Articulating specific and measurable targets and tracking progress through public disclosures can send market signals that further strengthen all of the above recommendations.

Our capstone recommendation is that PSUs, with support from their nodal ministries, can adopt the evidence-based approach used in this study to identify diversification strategies. This will future-proof these firms by continuing to bring revenues to the government, creating jobs, and sustaining their social value.

**Table ES1.** Risks and diversification strategies for CIL, IR, and NTPC

| CIL | IR | NTPC |
|---|---|---|
| **Cumulative short-term (2020–2030) CFaR at present value** | | |
| INR 127 billion | INR 614 billion | INR 29 billion |
| USD 1.8 billion | USD 8.7 billion | USD 0.4 billion |
| 13% risk to existing business | 21% risk to existing business | 4% risk to existing business |
| **Cumulative long-term (2020–250) CFaR at present value** | | |
| INR 415 billion | INR 2.112 trillion | INR 404 billion |
| USD 5.9 billion | USD 30 billion | USD 5.7 billion |
| 28% risk to existing business | 22% risk to existing business | 22% risk to existing business |
| **Diversification strategies** | | |
| **Setting up grid-scale solar photovoltaics (SPV)**<br>A target of 52 GW of installed SPV by 2050 can reduce CFaR by INR 94 billion (USD 1.3 billion). | **Leasing unused land for SPV**<br>Diversification strategy not quantified. | **Investing in battery storage**<br>A target of 16 GW battery energy storage systems by 2050 can reduce long-term CFaR by INR 59 billion (USD 0.8 billion). |
| **Developing integrated SPV manufacturing**<br>Diversification strategy not quantified. | **Phased passenger price reform**<br>2% annual reduction in under-pricing of long-distance air conditioned passengers can reduce CFaR by INR 140 billion (USD 2 billion). | **Strategic decommissioning of thermal power plants**<br>Accelerating phase-downs of approximately one third of the fleet by 2035 will reduce techno-economic risks due to lower capacity utilization. |
| **Planned reduction of inefficient coal assets**<br>Diversification strategy not quantified. | **Enhanced freight train speed**<br>Doubling average freight speeds from 25 km/h to 50 km/h by 2026 can generate additional gross revenue of INR 3,644 billion (USD 51 billion) by 2050. | **Piloting emerging technology options—offshore wind**<br>Diversification strategy not quantified. |

Source: Authors' estimates from financial analysis. Note: CFaR is calculated in present value terms by discounting at 12% per annum, but it varies by cost of finance. For example, at 10%, the CFaR over the long term amounts to CIL: INR 554 billion (USD 7.8 billion); IR: INR 2.8 trillion (USD 40 billion); and NTP: INR 549 billion (USD 7.7 billion).

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# Abbreviations and Acronyms

| | |
|---|---|
| **BAU** | business as usual |
| **BESS** | battery energy storage systems |
| **BRIDGE** | Building Roadmaps for Industrial Decarbonization and Green Economy |
| **CAGR** | compound annual growth rate |
| **CAPEX** | capital expenditure |
| **CEA** | Central Electricity Authority |
| **CFaR** | cash flow at risk |
| **CIL** | Coal India Limited |
| **EBITDA** | earnings before interest, taxes, depreciation, and amortization |
| **FCFE** | free cash flow expected |
| **FY** | fiscal year |
| **GEM** | green economy model |
| **GHG** | greenhouse gas |
| **GoI** | Government of India |
| **IEA** | International Energy Agency |
| **IR** | Indian Railways |
| **LDAC** | long-distance air conditioned |
| **MoC** | Ministry of Coal |
| **MoP** | Ministry of Power |
| **MoR** | Ministry of Railways |
| **MOSPI** | Ministry of Statistics and Programme Implementation |
| **MT** | million tonnes |
| **OCF** | operating cash flow |
| **PSU** | public sector undertaking |
| **SD** | system dynamics |
| **SDS** | Sustainable Development Scenario |
| **SOE** | state-owned enterprises |
| **SPV** | solar photovoltaic |
| **TPP** | thermal power plants |

# 1.0 Introduction

As of September 2022, nine out of the 11 listed *Maharatnas*—state-owned enterprises (SOEs) with particularly high levels of net worth and annual turnover—operate in the energy sector (Ministry of Finance, 2022; Press Information Bureau, 2019). They are profitable businesses providing regular dividends to the government, employ millions of people, offer energy security, and act as a vehicle of social development in communities where they operate. They are politically and administratively linked to key ministries and retain high investor confidence.

In India, these SOEs, also known nationally as public sector undertakings (PSUs), dominate the coal, oil, and gas sectors. As global climate dialogue moves toward accelerated ambition away from fossil fuels, these PSUs face headwinds driven by ambitious national targets on clean energy and the increasing cost competitiveness of solar- and wind-based power generation.

Along with government subsidies and investments made by publicly owned financing institutions, expenditures by SOEs form the third pillar of government support (Geddes et al., 2020). In fiscal year (FY) 2021, the capital expenditure (CAPEX) of the 14 largest energy PSUs stood at INR 1,400 billion (USD 18.8 billion), with 11 times more investments than in clean energy over FY 2014–2020 (Aggarwal et al., 2022; Viswanathan, Viswamohanan, Narayanaswamy et al., 2021). A continuation of this trend would increase the financial exposure of PSUs. However, as argued by Viswanathan and Aggarwal (2021), there is a strong economic and social case for PSUs to increase their clean energy ambitions and look beyond their existing business models.

Using the research methodologies of Köberle et al. (2020) as a foundation, this study looks at financial risks and diversification strategies for three important coal sector PSUs: Coal India Limited (CIL), NTPC, and Indian Railways (IR). The research further aims to support the Building Roadmaps for Industrial Decarbonization and Green Economy (BRIDGE) initiative housed under the Indian Institute of Management Calcutta's Centre for Development and Environmental Policy (IIM-C CDEP) (Telegraph, 2022). BRIDGE aspires to provide knowledge and business guidance for industries in India on energy transition.

This report has been prepared to foster critical discussion on how PSUs should plan for a new energy future. We are aware that firms themselves will have to do their own, more detailed calculations based on their own internal data and their own sense of priorities for diversification, but we hope that this report will serve as a template for strategic planning among state-owned firms in India and beyond.

# 2.0 Approach

Our analysis is based on the rationale that due to the increasing cost competitiveness of renewable energy vis-a-vis coal and policy priorities in the power sector, the revenues, cash flows, and financial health of CIL, IR, and NTPC are at risk. We have employed a mixed methodology with inputs from a literature review, data from government and peer-reviewed sources, analysis of publicly listed annual financial accounts, and consultations with experts. The analytical framework adopted in this paper is comprised of three key segments: energy modelling, financial analysis, and diversification strategies (see Figure 1).

**Figure 1.** Analysis overview

| Energy model | Financial analysis | Diversification strategies |
|---|---|---|
| Green economy model (GEM) | Annual report, financial statements, public disclosure | Expert consultations, annual reports, stated ambitions |
| Coal and renewable energy production and consumption trends, 2020–2050 | Cash flow at risk (CFaR) assessment | Opportunities for diversification |

## 2.1 Energy Model

The first segment uses the green economy model (GEM) to explore future scenarios of the Indian energy system in the short (2020–2030), medium (2020–2040), and long terms (2020–2050). GEM uses system dynamics as its underlying methodology. It works at the economy level, where various actors are interconnected via explicit cause-effect relationships with feedback loops that can be either reinforcing or balancing. Further details on GEM design, assumptions, and inputs have been described in Appendix A.

To model future scenarios, a review of existing energy models was conducted. A key limitation among recent studies, including the Central Electricity Authority's (CEA) Optimal Generation Mix, was capturing the demand shock of COVID-19 (CEA, 2020). Scenarios in the International Energy Agency's (IEA's) *India Energy Outlook 2021* were used as a benchmark, as they both factor in COVID-19 and extend to 2050 (IEA, 2021a). Two scenarios were developed in GEM:

- **Business As Usual (BAU)** – This was aligned with the IEA's Stated Policies Scenario and captures trends based on existing plans, including reaching 450 GW of renewable energy capacity by 2030.
- **Aspirational** – This was aligned with the IEA's Sustainable Development Scenario (SDS), which corresponds with reaching net-zero emissions in the 2060s.

At the time of writing, the power sector is recovering from a coal-shortage crisis. Government has pushed for increased coal imports to meet target stockpile levels ahead of the monsoon season, when production usually drops in coal mines. However, this is a very short-term directive, with the broader objective being reducing dependence on imports. The primary analysis of this study was done before the current crisis and assumes a trend toward reducing imports.

It must be stated that these scenarios do not represent determinative forecasts or pathways that individual businesses can choose to follow. In reality, the BAU scenario is quite unlikely, with countries expected to periodically raise ambition under the Paris Agreement. Even the Aspirational scenario may not be sufficient to meet the Paris Agreement goal of limiting average temperature rise to no more than the 1.5°C. This goal would require a further increase in ambition—but the IEA's SDS was used because there is no granular country-level data available for the IEA's net-zero scenario, which was published for the first time in 2021.

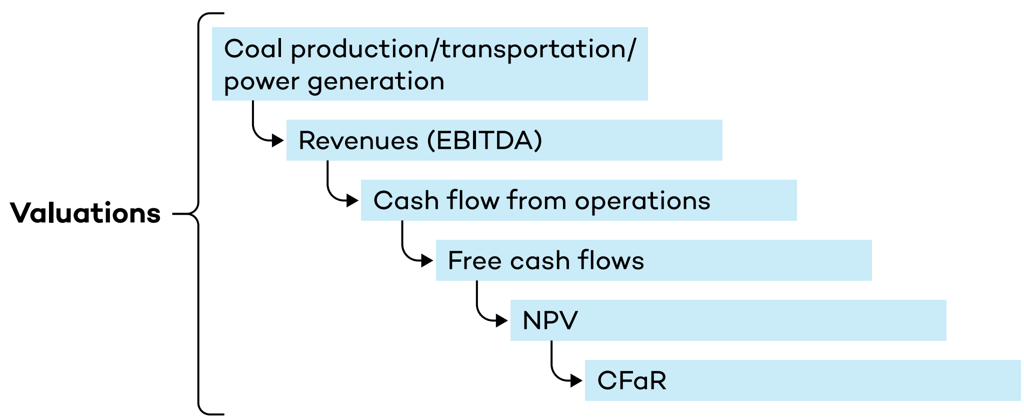
## Financial Analysis

The impact on cash flows at the firm level is calculated in the scenario where India moves from BAU to the Aspirational scenario. Outputs from GEM were used as key input variables, such as coal demand, production, and consumption; power generation; and installed capacities of different energy technologies. Appendix B provides a detailed list of assumptions used.

Figure 2 depicts the flow of the analysis. Inputs from GEM and existing market shares are used to calculate the firm-level coal production, transportation, and consumption under the BAU and Aspirational scenarios. Based on past financial performance calculated through the compound annual growth rate (CAGR), appropriate per-unit financial metrics were estimated. Depending on the firm analyzed, earnings before interest, taxes, depreciation, and amortization (EBITDA) and cash flow from operation and net revenues per unit of coal produced (CIL), transported (IR), or consumed (NTPC) were estimated. Together, they were used to arrive at estimates of free cash flows.

In both scenarios, the net present values (NPVs) of cash flows were calculated, discounting at 12% per annum. The difference between the two scenarios indicates the "risk spectrum" or the risk to the businesses if India increases its sustainability ambition. The CFaR is the difference between the NPVs of the Aspirational and BAU scenarios, and a positive value indicates the presence of risk.

**Figure 2.** Financial risk analysis framework



## Diversification Strategies

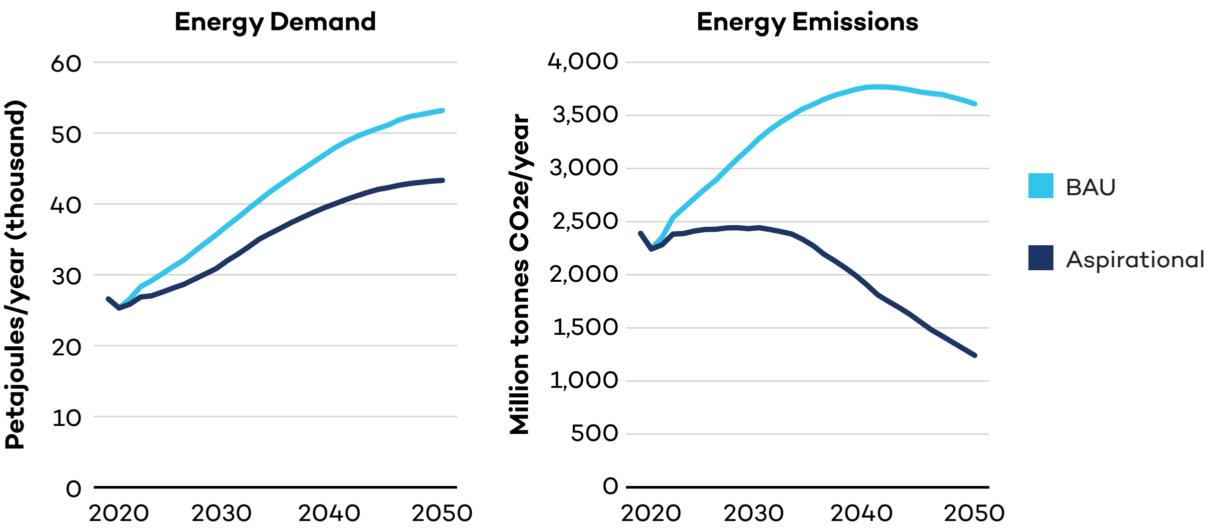
The final segment of our analysis investigated diversification actions for CIL, NTPC, and IR. Consultations were conducted with the three PSUs, ministries, regulators, and experts. The findings were cross-referenced with announced commitments for clean energy and existing ambitions (Aggarwal et al., 2022). Where possible, they have been estimated along with the financial analysis. As a result of this approach, the majority of strategies that were identified are based on existing considerations among PSUs. A renewed push from the government could drive innovation into further areas that have not been considered in this study. Additionally, the strategies considered for assessment do not include technologies that are reliant on fossil fuels like natural gas, grey hydrogen, clean coal, coal gasification, or coalbed methane due to their strong likelihood of not being aligned with the 1.5°C goal (Bois van Kursk & Muttitt, 2022). Also, strategies reliant on forms of carbon capture and utilization or storage have been excluded due to the limited technological progress and risk being locked in to existing fossil businesses (Calverley & Anderson, 2022).

# 3.0 Context

## 3.1 What Energy Transition Pathways Mean for India

As described in the previous section, the two scenarios modelled under GEM are aligned with the IEA's scenarios. Under the BAU scenario, energy demand and greenhouse gases (GHG) follow a similar trend, while the Aspirational scenario shows a decoupling of the energy sector, with demand increasing despite GHG emissions (see: Figure 3).

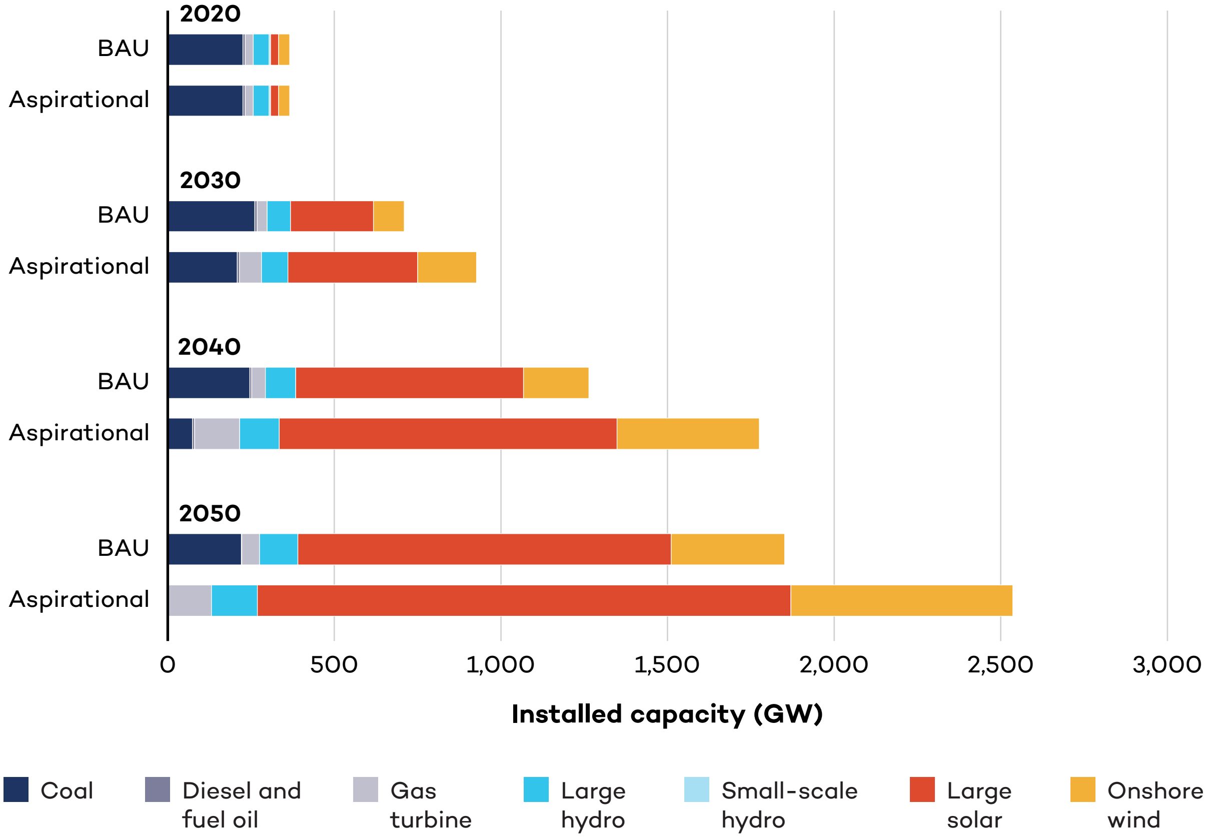
**Figure 3.** All-India energy demand and GHG emissions (2019–2050)




Note: $CO_2e$ = carbon dioxide equivalent
Source: Authors' estimates based on GEM modelling.

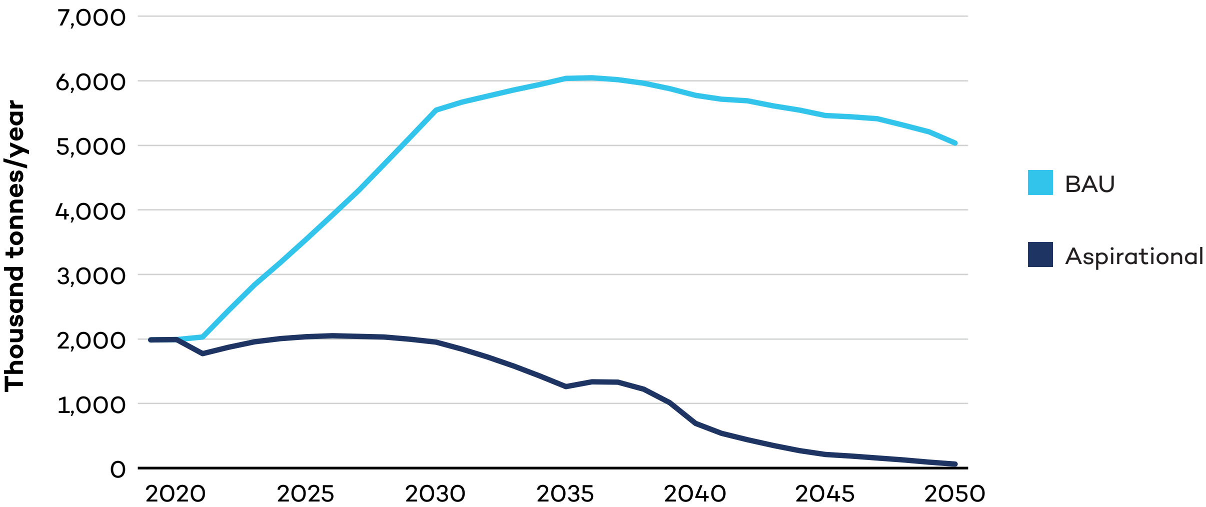
The two drivers behind GHG reductions are the rapid scaling-up of renewable energy in power generation and the sharp reduction in coal-fired power generation (see Figure 4). BAU is based on the existing target of 450 GW of renewable energy capacity being met by 2033, 3 years after the current goal. By 2030, it considers 341 GW of solar and wind, while the Aspirational pathway involves installing a significantly higher 566 GW of solar and wind. In contrast, by 2040, the Aspirational pathway considers only 74 GW of coal power in comparison to 246 GW under BAU. Further coal power generation completely phases out by 2050 in the Aspirational scenario. The underlying IEA scenarios are largely built around existing technologies on which there is good data to form the basis of projections. As they emerge, clean technology options like green hydrogen, offshore wind, or battery storage may also become key drivers that can increase the pace of change and the scale of ambition.

**Figure 4.** National pathways on installed power generation capacity by fuel type




Source: Authors' estimates based on GEM modelling.

**Figure 5.** Air pollution levels from power generation under the two scenarios (2019–2050)




Note: Value represents aggregate emissions from the following pollutants: ammonia, black carbon, carbon monoxide, organic carbon, nitrogen oxides, non-methane volatile organic compounds, and particulate matter 10 and 2.5.

Source: Authors' estimates based on GEM modelling.

The Aspirational pathway also brings greater benefits to society. Due to sharp reductions in coal power, air pollution would follow suit and significantly drop. In turn, this contributes to greater economic revenue through improved productivity (see Figure 5).

## 3.2 Coal PSU Profiles

Table 1 presents an overview of the three PSUs based on publicly available information. Despite more recent estimates, FY 2020 values were used to represent data on operations, to be consistent with values used in the financial analysis, and to represent business before the onset of the COVID-19-induced disruptions. Through this exercise, it was observed that publicly available data was limited on investments between fossil and clean assets, financial exposure to climate risks, the carbon footprint of businesses, and progress made toward clean energy targets.

**Table 1.** A summary of the coal PSUs analyzed

| Governance | Coal business | Diversification plans | Social responsibilities |
|---|---|---|---|
| **Coal India Limited (CIL)** | | | |
| CIL is a *Maharatna* company under the administrative control of the Ministry of Coal (MoC) and the Government of India (GoI) (Ministry of Finance, 2022). The GoI is the majority shareholder, with 66.13% of total equity shares in the company. Two major public financing institutions, Life Insurance Corporation and State Bank of India, also hold significant shares as of FY 2021 (CIL, 2021). | CIL accounts for 83% of India's overall coal production, with 602 million tonnes (MT) during FY 2020 (CIL, 2021). CIL has set targets to produce 1 billion tonnes by FY 2024. Coal prices are administratively controlled, and CIL sells coal at notified prices that undergo periodic revisions. In FY 2020, CIL's total income was INR 1,025 billion (USD 14.4 billion), and it paid INR 51 billion (USD 0.7 billion) in dividends to the government (CIL, 2021). | CIL has set up two subsidiaries for solar photovoltaic (SPV) power generation and integrated photovoltaic manufacturing. Plans include a partnership with NTPC on a 50 MW solar power project, setting up 3 GW of solar by 2024, and participating in integrated SPV module manufacturing bids (Aggarwal et al., 2022; Viswanathan, Viswamohanan, Aggarwal et al., 2021, p. 94). In May 2022, CIL released an action plan documenting its diversification efforts (MoC, 2022a). | CIL is one of the largest employers in India, with over 272,000 stated employees and several thousand more through sub-contractors (CIL, 2022).<br>Its corporate social responsibility expenditure in FY 2021 was INR 5,540 million (USD 74 million), with INR 2,690 million (USD 35 million) for COVID-19 relief measures (CIL, 2021). |

| Governance | Coal business | Diversification plans | Social responsibilities |
|---|---|---|---|
| **Indian Railways (IR)** | | | |
| IR is the state-owned railway company and is under the administrative control of the Ministry of Railways (MoR). It is 100% owned and operated by GoI, with its strategic plans developed by the Railway Board under MoR. IR receives budgetary support and borrows from Indian Railway Finance Corporation to supplement internal revenues to meet expenses (CAG India, 2021). | Losses from passenger transport were INR 634 billion (USD 9 billion) in FY 2020 (CAG India, 2021). IR uses revenues from freight services to cross-subsidize passenger fares.<br>Coal is the most important commodity, accounting for 49% of freight traffic and revenue in FY 2020 (IR, 2021). An in-depth assessment by Kamboj and Tongia (2018) identified that the relationship between coal and IR's business is unsustainable. | IR is looking to diversify its freight mix and reduce its dependence on coal (Khan, 2021). Business Development Units have been formed in each railway zone, and the National Rail Plan (NRP) 2030 looks at enhancing IR's infrastructure by 2030 to cater to the traffic requirements until 2050 (MoR, 2020).<br>IR has announced plans to set up 20 GW of solar plants in unused lands by 2030 (Standing Committee on Railways, 2021). | IR has over 1.2 million regular employees, with track length close to 100,000 km, which carried more than 8 billion passengers and 1.2 billion tonnes of freight in FY 2020 (IR, 2021).<br>IR routinely undertakes uneconomic activities to serve social obligations and is deployed during national emergencies. |

| Governance | Coal business | Diversification plans | Social responsibilities |
|---|---|---|---|
| **NTPC** | | | |
| NTPC is a *Maharatna* company under the administrative control of the Ministry of Power (MoP), which holds 51.1% of its shares, with Life Insurance Corporation and State Bank of India holding significant amounts (NTPC, 2021a). The Central Electricity Regulatory Commission and the CEA are the commercial and technical regulators overseeing NTPC's operations. | By owning and operating 64.5 GW of power generation capacity, NTPC produces 17% of the country's total power generation. Out of this, 53 GW is from coal power plants (NTPC, 2021a).<br>NTPC reported a total income of INR 1,350 billion (USD 17 billion) and has paid an interim dividend of INR 38.8 billion (USD 0.5 billion) in FY 2022 (NTPC, 2022; The Hindu, 2022). | NTPC has set an ambitious target of 60 GW of renewable energy capacity by 2032 and set up NTPC Renewable Energy Limited, a subsidiary, to drive this business.<br>NTPC is looking to expand its clean energy operations, including battery storage, green hydrogen, and thermal power plant repurposing.<br>NTPC has signed Memorandums of Understanding with Oil and Natural Gas Corporation, Indian Oil Corporation Ltd, and CIL to expand clean energy (Aggarwal et al., 2022). | NTPC's corporate social responsibility expenditure for FY 2021 stood at INR 4,190 million (USD 56 million) (NTPC, 2021a).<br>As the leading power generator, NTPC is key to meeting goals on electricity access and is often at the forefront of electrification efforts. |

Source: Authors' analysis based publicly reported information

# 4.0 Key Findings

This section reports the results of an analysis of the three PSUs. Financial years in India run from April 1 to March 31 and are numbered based on the year they end. In our analysis, a calendar year corresponds to the FY with most months in the calendar year. For example, 2020 corresponds to FY 2021, which runs from 1 April 2020 to 31 March 2021. Most financial estimates are reported in billions, whereas national reporting uses *crore*, where 1 billion equals 100 crore.

## 4.1 Coal India Limited

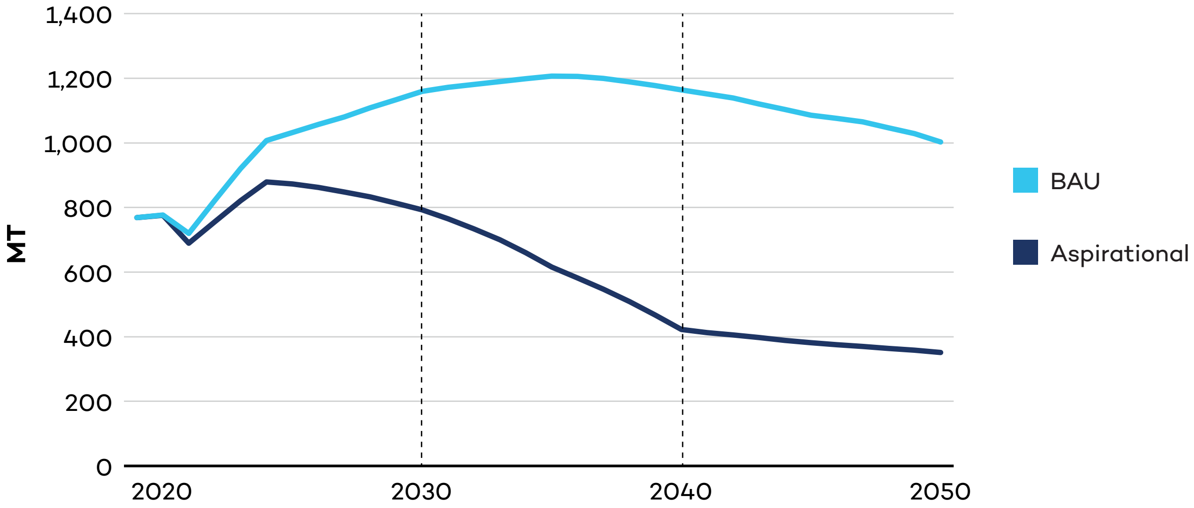
CIL's business is predominantly made up of coal mining, with net coal sales accounting for 87% of its total revenue in FY 2020 (CIL, 2021). It mined 602 MT in the same year, or 78% of India's total domestic coal production (CIL, 2021). The coal is predominantly steam coal used for power generation. IEA scenarios suggest that CIL faces significant risks in future years: national coal production will fall as the clean energy transition gathers pace. In the absence of firm government targets on coal peaking and phase-down, the exact pace of change is unknown, which also creates risk.

In FY 2020, India's total consumption stood at 1,008 MT, with the power sector being the biggest consumer at 611 MT. This was met by 768 MT in domestic production and the rest through imports. Two short-term government targets currently exist on production: first, a gradual phase-out of imports and second, CIL reaching 1 billion tonnes of production by FY 2024 (Business Today Desk, 2021; PTI, 2022b). The government has also acknowledged a phase-down of coal under the Glasgow Climate Pact but does not have a timeline or quantitative targets (United Nations Framework Convention on Climate Change, 2021).

Figure 6 illustrates national coal production for use across all sectors and across all grades. Over 2020–2050, it shows BAU and Aspirational pathways, broadly consistent with the target for net-zero by 2070. Projections have been aligned with short-term targets on production and changing coal demand as a result of renewable energy trends. In the BAU scenario, production is expected to increase for the next decade, peaking at 1,198 MT in 2035. In the Aspirational scenario, peaking takes place a decade earlier, and the peak is 28% lower than BAU. The difference sharply increases in the medium term, from a gap of 367 MT in 2030 to 741 MT in 2040. The long-term trend of peaking and decline is evident across both scenarios.

In reality, BAU is highly unlikely to accurately depict future trends, and even the Aspirational scenario may underestimate the pace of change in 2030–2040 because the Paris Agreement is designed so that countries will regularly ratchet up climate ambition. This means that current aspirations may well increase, and various analyses suggest that global coal phase-out is needed between 2040 and 2050 if the world is to limit warming to no more than 1.5°C (Bois van Kursk & Muttitt, 2022).

**Figure 6.** Pathways on national coal production (MT), 2020–2050



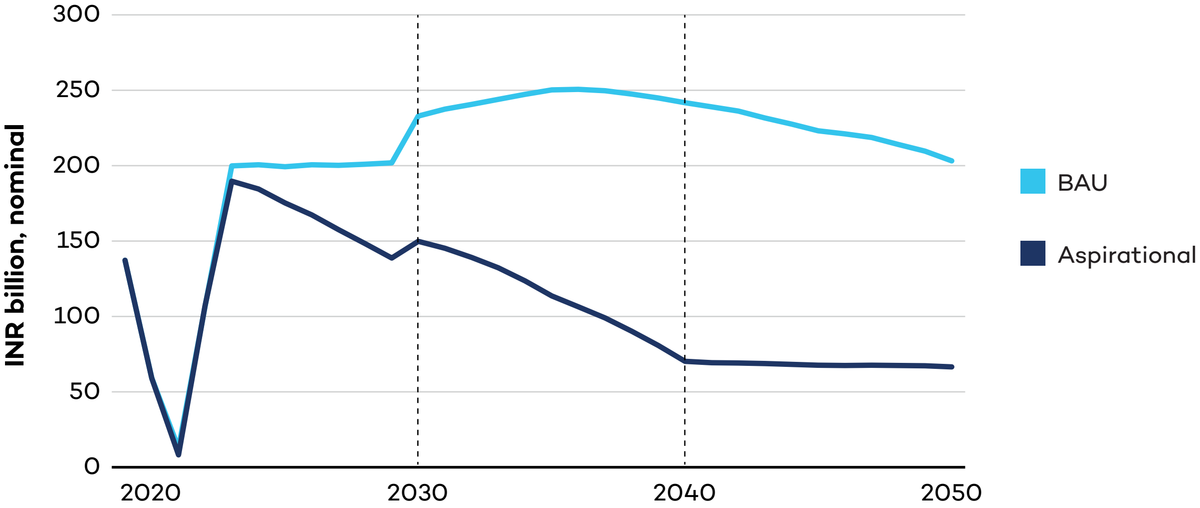

Source: Authors' estimates based on GEM modelling.

## Financial Risks

As shown in Figure 7, scenarios on CIL's free cash flow were estimated from 2020–2050 (FY 2021–2051). CIL's share of total national production is assumed to remain constant. Cash flow per unit of coal was estimated from recent CIL financial statements and the volatility in the initial years reflects observed impacts of COVID-19 (see Appendix B for full details). The scenarios anticipate that free cash flow will recover along with the economy and targets for increased short-term coal production, reaching around INR 200 billion (USD 2.5 billion), and then closely follow trends in production: under BAU, free cash flow will gradually increase and peak around FY 2036 before declining to FY 2024 levels in FY 2050; in the Aspirational scenario, it will decline more sharply, 21% lower by FY 2031 from the peak in FY 2024.

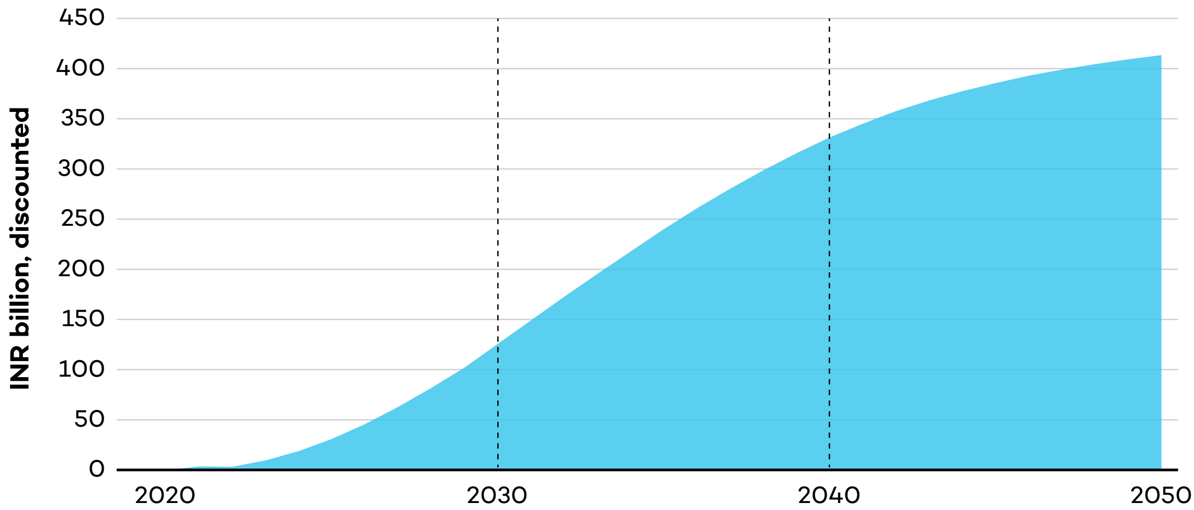
In present value terms, discounting at 12% per annum, the total CFaR over the long term is INR 415 billion (USD 5.9 billion), which corresponds to a 28% reduction in NPV between the BAU and Aspirational scenarios. As seen in Figure 8, the period in which CFaR accumulates most rapidly is the medium term, from 2030–2040, when CFaR rises in value by 2.6 times. This indicates a need for risk mitigation strategies that have achieved scale by the medium term.

**Figure 7.** Forecast nominal free cash flow (CIL), 2020–2050




Source: Authors' estimates from financial analysis.

**Figure 8.** Cumulative cash flow at risk (CIL), discounted, 2020–2050




Source: Authors' estimates from financial analysis.

As summarized in Table 2, more than a quarter of CIL's NPV would be at risk if India were to follow an Aspirational pathway. Diversification strategies can mitigate this risk.

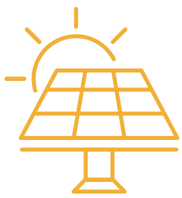
**Table 2.** Financial risks of coal-dependency for CIL (INR billion), 2020–2050

| | NPV (BAU) | NPV (Aspirational) | CFaR | % |
|---|---|---|---|---|
| Short term (2020–2030) | 994 | 867 | 127 | 13% |
| Medium term (2020–2040) | 1,391 | 1,058 | 333 | 24% |
| Long term (2020–2050) | 1,509 | 1,094 | 415 | 28% |

Source: Authors' estimates from financial analysis.

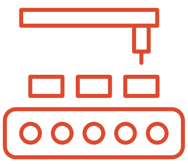
## Potential Diversification Strategies

Through a review of CIL's Action Plan 2022–23, publicly available documentation, and expert consultations, we short-listed several potential diversification strategies focused on energy, as follows (MoC, 2022a):



**Setting up grid-scale SPV:**

SPV is well established, with strong growth prospects beyond 2050. CIL has already expressed interest in developing SPV, with a target of installing 3 GW by 2024, and has established two subsidiaries: CIL Solar PV and CIL Navikarniya Urja Limited (CIL, 2021; PTI, 2020). NLC India, another coal mining PSU, has made significant forays into the sector, which establishes the business feasibility (Mercom, 2021).



**Developing integrated SPV manufacturing:**

CIL has expressed interest in SPV manufacturing, having submitted an ultimately unsuccessful bid to set up 4 GW of capacity under the recent production-linked incentive scheme to serve the domestic market (Chatterjee, 2021). Consultations suggested that CIL should continue to participate in subsequent production-linked incentive bids. Research suggests that large PSUs may be particularly well placed to establish early-stage manufacturing, given the high upfront investments required and PSUs' strength in raising capital compared to smaller firms (Viswanathan, Viswamohanan, Narayanaswamy et al., 2021).

**Planned reduction of inefficient coal assets:**

As coal demand drops in the mid-term, CIL can proactively plan mine closures, reduce operation and maintenance costs, or lease mines to private contractors. These measures can increase revenue for every tonne of coal mined and thereby reduce risk exposure. However, these changes must be enacted within the principles of just transition (Banerjee, 2021, p. 26).

In later consultations, battery storage emerged as an option, which has not been integrated into our analysis. However, we have considered the potential for battery storage in NTPC (see Section 4.3). CIL also owns vast tracts of land that can be leased or used for carbon credits subject to regulatory clearance (MoC, 2022b).

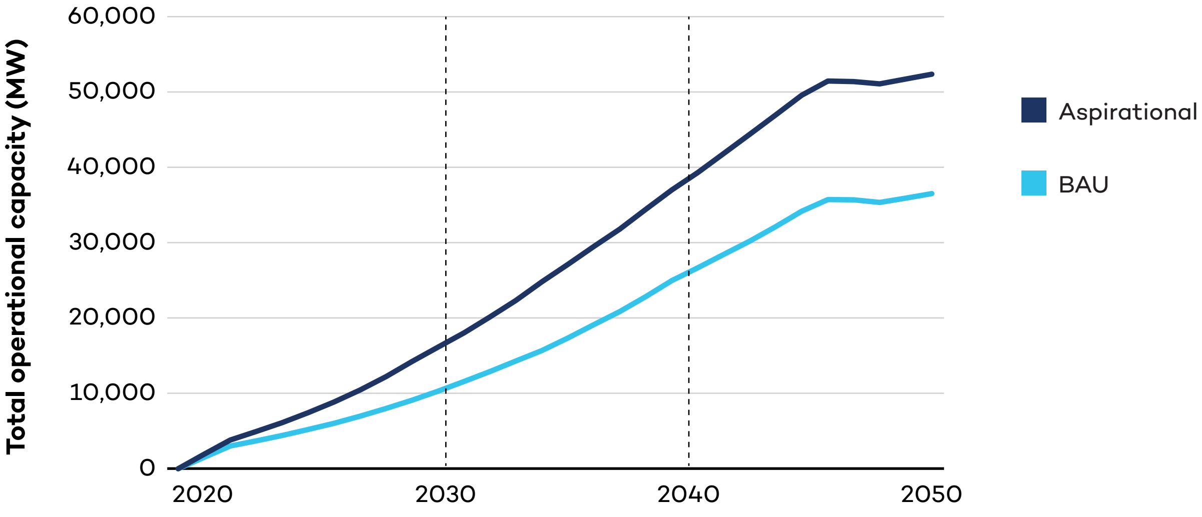
Announced strategies that rely on fossil fuels, including clean coal technologies, coal gasification, and carbon capture, have not been considered in the analysis (see Section 2). A number of non-energy diversification actions were also identified but not explored in detail. Building on its expertise in mining, CIL is well placed to expand into mining for other minerals, such as bauxite or critical minerals required for clean energy technology manufacturing. There are, however, several policy and technology limitations in the sector, and care must be taken to acknowledge climate risks related to mining for other minerals as well (Chadha & Sivamani, 2022).

## Risk Mitigation Potential: Diversifying into grid-scale photovoltaic

We selected grid-scale photovoltaic to examine the extent to which diversification can help mitigate CIL's CFaR. This is because, among the short-listed options, it is the most feasible to estimate future cash flows given the relative maturity of this technology in India and the consequent accessibility of good benchmark data. Today, CIL's stated ambition is to build 3 GW of grid-scale SPV by 2024, equal to 4.14% of India's total estimated capacity for that year. We assumed that CIL might aim to maintain this share under both the BAU and Aspirational scenarios, as illustrated in Figure 9.

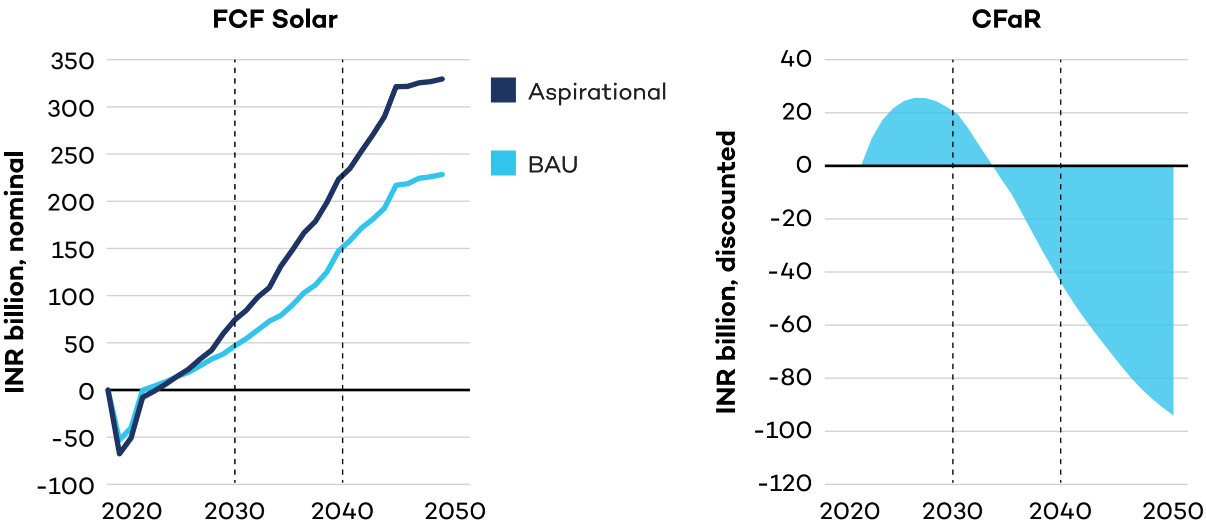
CAPEX and revenues associated with grid-scale SPV were benchmarked to leading private sector developers in India. As shown in Figure 10, the free cash flow trends are negative initially due to SPV's capital-intensive nature. But by the short term, including with greater investment volumes in the Aspirational scenario, there is a positive free cash flow. By FY 2034, CFaR from solar business turns negative, which is to say, an Aspirational pathway would imply a reduction in risks based on CIL's current solar ambitions. This further accumulates, reaching INR 94 billion (USD 1.3 billion) by 2050. Given SPV's 25-year lifetime, later installations would also contribute revenue beyond our assessment period.

**Figure 9.** Forecast CIL aggregate solar operational capacity (GW), 2020–2050




Source: Authors' estimates based on GEM modelling.

Figure 10. Forecast CIL free cash flow (nominal) and cumulative cash flow at risk (discounted) from solar




Source: Authors' estimates from financial analysis.

If CIL adopts this mitigation strategy, then its long-term net CFaR—accounting for both the "positive" risk of coal and the "negative" risk of SPV between BAU and Aspirational pathways—would drop from 28% to 19%, as shown in Table 3. In the short term, however, the overall CFaR doubles between FY 2021 and FY 2031 and comes to INR 321 billion (USD 4.5 billion) by the end of the assessment period. Using this same approach, we can also estimate the level of ambition required for SPV to completely mitigate coal-related business risks: targets for SPV would need to increase 4.4 times, to 13.2 GW by 2024, and maintain an 18.2% share of India's total installed capacity in each year thereafter. In reality, adopting just one strategy to mitigate risk is unlikely, but articulating why ambition is sufficient to offset risk would be a good evidence-based approach to setting the right level of ambition across a range of targets.

Table 3. Net cash flow at risk for CIL (INR billion), including coal and SPV activities

| | Change in NPV | | CFaR | | |
|---|---|---|---|---|---|
| | BAU | Aspirational | Solar | Overall | % |
| Short term (2020–2030) | -27 | -46 | 19 | 146 | 15% |
| Medium term (2020–2040) | 87 | 134 | -47 | 286 | 19% |
| Long term (2020–2050) | 185 | 279 | -94 | 321 | 19% |

Source: Authors' estimates from financial analysis.

## Key Takeaways

### MoC

- **Commission phase-down planning and strategy:** In light of the importance of ministerial instruction to enable major changes in the business of a PSU, it is recommended that the MoC provide CIL with a mandate to assess coal-related risks, including a stocktake of assets under threat of stranding, and identify strategies for diversification.
- **Set a mission for CIL to help deliver clean energy targets:** In interagency planning on interim targets and pathways for net-zero, it is recommended that the MoC suggests a role for CIL to help deliver a share of India's future clean energy system that is consistent with CIL's own assessment of its best strategic options for diversification.

### CIL

- **Assess risk and set a vision for diversification to mitigate risks.** An internal CIL assessment can draw on detailed disaggregated data and ensure full ownership of findings. Publicly reporting these findings would strengthen market signals of the intent to become a clean energy company.
- **Increase clean energy ambition, in line with business risks:** CIL's current ambitions are low compared to some other PSUs like NTPC, and there is no clear rationale linking ambition to risks. As exemplified in this preliminary analysis, increasing SPV targets by 4.4 times could completely offset all coal-related risks based on current national aspirations. It is further recommended that CIL articulate a roadmap for its newly formed SPV subsidiaries, CIL Solar PV and CIL Navikarniya Urja Limited.
- **Invest early in diversification while fossil revenues are strong:** The greatest accumulation of CFaR for CIL is anticipated for the period 2030–2040, but clean energy investments would be required in the immediate future so that assets are financially self-sufficient in time.

Further, CIL's status as a government *Maharatna* is underpinned by its importance in coal mining communities across India. Any strategic thinking on diversification is recommended to consider how it can align with CIL's social and environmental responsibilities (see Box 1).

### Box 1. PSUs as key actors in India's just transition

Just transition is a relatively new yet critical pillar of India's energy transition journey. Both coal demand and formal jobs in the coal sector may soon peak. While clear government directives for a coal phase-down are yet to roll out, past experiences from across the world show that the coal transition takes a long time and requires the adoption of comprehensive economic diversification strategies by the state (Ruppert Bulmer et al., 2021).

Globally, most discussions of a just energy transition focus on phasing out a sector, closing a plant, or restructuring. However, in some contexts, state entities can have the capacity to transform, contributing to a just transition by generating new jobs and creating new sectors (Smith, 2017, p. 11). The most notable example of this is Ørsted, the Danish offshore wind firm that was once an oil and gas company (Muzondo et al., 2021, p. 54).

As the largest employers in the coal value chain, the ambition, actions, and profitability of PSUs like CIL, IR, and NTPC over the next decade will be important drivers of whether the energy transition is just. Beyond formal employment, PSUs are also important actors in defining these shared values between the state and coal communities through political representation, rehabilitation packages, local area development, and corporate social responsibility. While undertaking an internal assessment on diversification strategies, these PSUs can prepare for just transition dialogues by stocktaking relevant indicators such as workers that require re-skilling and the vintage of the fleet.

The latest estimates show that there were around 745,000 direct coal mining jobs in FY 2020 (Pai & Zerriffi, 2021). In most of India's top 22 mining districts, which produce at least 10 MT or more coal per year, 50% of the population is "multidimensionally poor," twice the Indian average of 27.5% (Bhushan et al., 2020). Further, in one of the top coal mining districts of Ramgarh in Jharkhand, more than 40% of households within a radius of 3 km from coal mines derived an income from coal, and only 29% of them had formal coal mining jobs in 2020. The larger share (71%) included coal gatherers, sellers, labourers, and contractual workers (Bhushan et al., 2020).

This clearly shows that any transition in the business model and portfolio of India's coal-dependent PSUs will not only have a direct impact on its formal workforce but an even larger impact on surrounding coal-dependent communities. While coal mining is still profitable overall, as per recent data on 420 operational mines of CIL, 292 were loss-making, thereby increasing the risk of mine closures, reduced compensation packages, and falling dividends for the state exchequer (Bhushan et al., 2020). This shows the rapid and rising need to plan around a just energy transition. Importantly, this also shows that coal communities will require more stewardship from state entities.

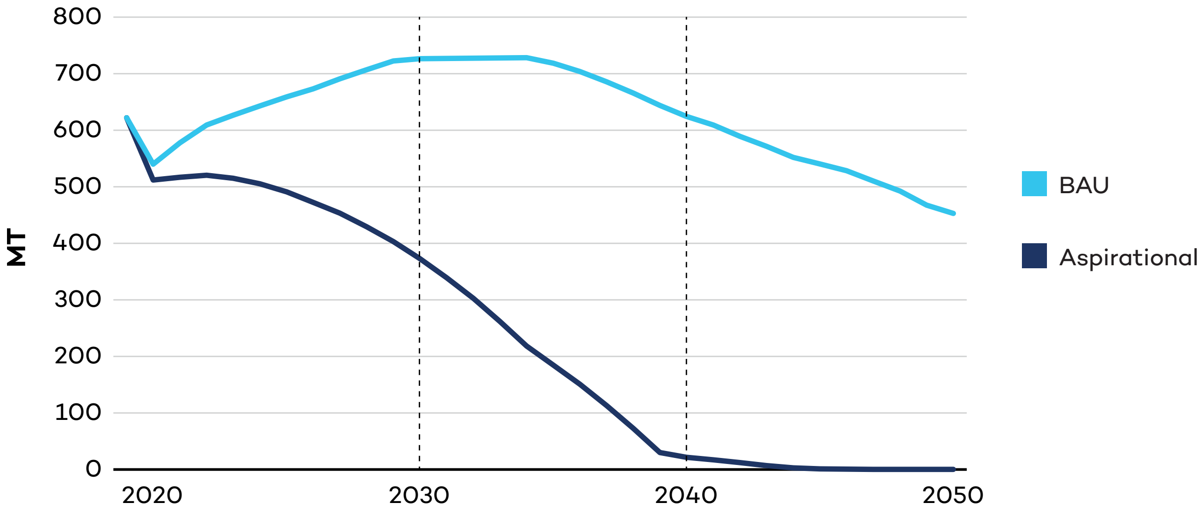
Recognizing this, in a recent move, the MoC has decided to set up a just transition division to draft sustainable coal mine closure plans, starting with two pilot districts (Jai, 2022; MoC, 2022a). While MoC's initiative is intended to focus on mines that are closing for economic reasons and that are independent of the climate-induced energy transition, it could still generate lessons for forward-looking pathways for a phase-down of coal.

## 4.2 Indian Railways

IR is a wholly government-owned business serving the important role of moving passengers and freight across the country. Coal is an important commodity for IR, accounting for 41% of freight traffic and 34% of gross revenues in FY 2020 (IR, 2021). Profits from coal freight are used to subsidize passenger fares (Garg et al., 2020; Kamboj & Tongia, 2018). IEA's scenarios indicate that India's coal consumption is expected to fall over the next decades, and this would directly impact IR's business. Out of the total coal freight of 587 MT, IR transported 254 MT of coal to the power sector in FY 2020 (IR, 2021). With increased renewable energy capacity targets and a commitment to coal phase-down, the power sector is expected to decarbonize first.

In Figure 11, India's net coal consumption for power generation is shown across two scenarios between 2020 and 2050: BAU, based on stated commitments, and an Aspirational scenario that is aligned broadly with India's 2070 net-zero targets. Under BAU, coal consumption peaks by 2035 at 728 MT, and by 2050, it falls below 2020 levels. In the Aspirational scenario, peak coal consumption for power has passed already, and it is expected to see a dramatic phase-down in the short and medium terms, with negligible consumption from 2040 onwards. It must be noted that this does not include coal used in non-power sectors. Our analysis for IR focuses on the coal-to-power value chain.

**Figure 11.** Pathways on national coal consumption for power generation (MT), 2020–2050




Source: Authors' estimates from GEM results.

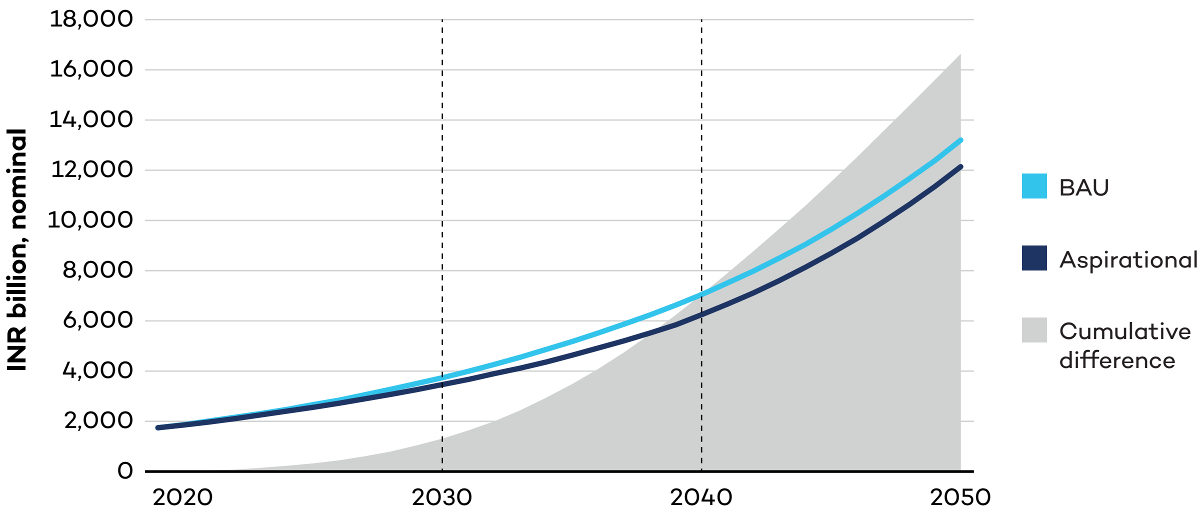
On average, across FY 2016–2020, IR's coal freight to the power sector was equivalent to 47% by volume of national consumption (IR, 2021). In our analysis, we have assumed the same proportion going ahead. Under the draft NRP by the MoR, domestic coal freight has been set to a constantly increasing trajectory, reaching 2,207 MT by 2050 (MoR, 2020). Due to a major difference in assumptions, the coal projections in the NRP could not be reconciled without our energy model and have not been integrated into this analysis.

## Financial Risks

Our financial assessment method for IR differs from CIL and NTPC due to differences in reporting. Annual cash flow statements are not reported, and since IR functions as a monopoly, its operations cannot be benchmarked to other businesses. Based on CAGR from FY 2010 to FY 2019, forecasts have been made on total (gross) revenue receipts and expenditures. Net revenue (gross revenue minus expenditure) has been used to identify the NPV and aggregate CFaR (see Annex B).

Figure 12 shows the forecast gross revenue in nominal terms over 2020–2050. The trend steadily increases across both scenarios as the analysis assumes a fixed positive annual growth rate in gross revenues from all business aspects except coal transported for power generation. The difference between the two scenarios is due to falling revenues from coal transported for power generation, which cumulatively reaches INR 16,642 billion (USD 234 billion) by FY 2051. The net revenue follows a steadily increasing trend similar to gross revenue, as the expenditure remains the same across both scenarios. However, IR has been historically prone to losses and is notably vulnerable to negative net revenue (net losses) in cases of shortfalls in freight collections or greater-than-expected expenditures (CAG India, 2021).

**Figure 12.** Forecast of nominal gross revenues for IR (INR billion), 2020–2050




Source: Authors' estimates from financial analysis.

As shown in Table 4, discounting at 12% per annum, the NPV from net revenues goes up by over 3 times in the long term across both scenarios. The CFaR increases over the short and medium terms reaching INR 1,564 billion (USD 22 billion), or 24%, before tapering to 22% in the long term due to revenues from other sources picking up. However, this CFaR is a conservative estimate and would likely be much larger in the case of lesser-than-expected growth in revenues from non-coal freight or a sustained increase in expenditures.

**Table 4.** Financial risks of coal-dependency for IR (INR billion), 2020–2050

| | NPV (BAU) | NPV (Aspirational) | CFaR | % |
|---|---|---|---|---|
| Short term (2020–2030) | 2,855 | 2,241 | 614 | 21% |
| Medium term (2020–2040) | 6,501 | 4,937 | 1,564 | 24% |
| Long term (2020–2050) | 9,452 | 7,339 | 2,112 | 22% |

Source: Authors' estimates from financial analysis.

## Potential Diversification Strategies

Given IR's ownership structure, it is better to not view it as a profit-maximizing enterprise. IR gets budgetary support and loans from the Indian Railway Finance Corporation, and in FY 2020, this was equivalent to 80% of internal revenues (CAG India, 2021). Hence, financial surpluses produced by IR's business and operational efficiency remain important for its viability. Large budgetary support disincentivizes planning for financial risks due to the energy transition away from coal.

IR has stated plans to lease unused land to set up 20 GW of solar plants by 2030 (Standing Committee on Railways, 2021). In the long term, green hydrogen can play an important role in low-carbon heavy freight. It can align with IR's own freight business but remains to be proven. However, no roadmap has been made yet, and it is difficult to establish the financial viability with the available information. Due to the financial burden IR can have on the budget and key public financing institutions, two risk mitigation strategies have been identified based on its wider business operations.

**Phased passenger price reform:**

IR recovers an average of 53% of the costs incurred for passenger travel and has unsuccessfully attempted to reduce losses through a scheme where passengers can voluntarily opt out of subsidies (IANS, 2019). Due to political sensitivities, gradual price reform is more viable and can reduce financial risks through avoided losses.

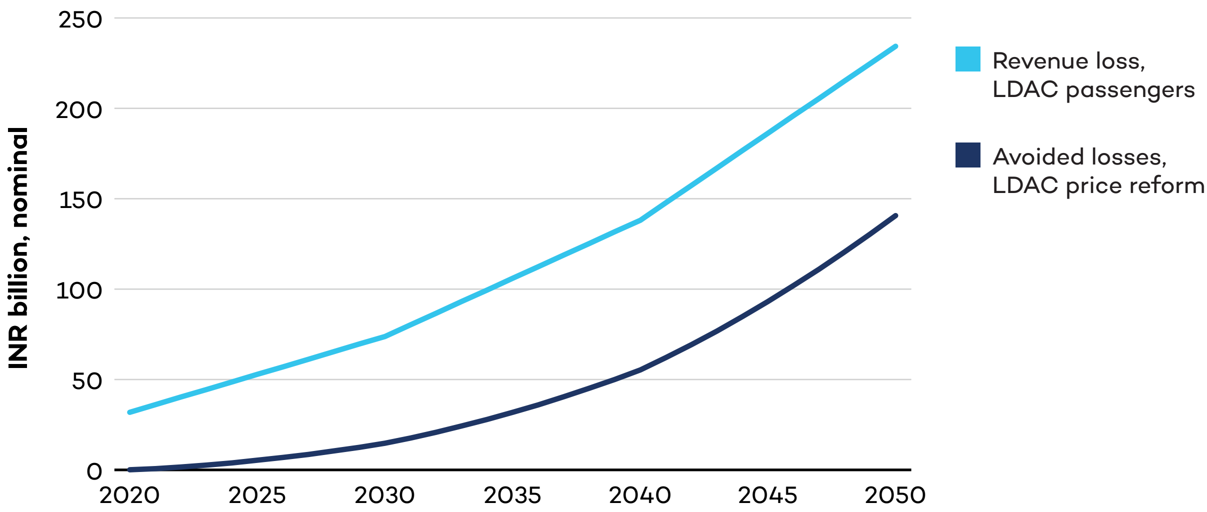
**Enhanced freight train speed:**

Increasing the market share of national freight can generate additional revenue that can offset any risks. It also improves supply chains and strengthens domestic industries. Under Mission Raftaar, the government tried to double average freight speeds; it is one of the strategies considered in the NRP (IR, 2016; MoR, 2020).

## Risk Mitigation Potential: Phased passenger price reform

Rationalizing passenger fares has been challenging due to the fact that low passenger fares are intentionally provided for social welfare objectives. In FY 2020, IR carried over 8 billion passengers at a loss of INR 637 billion (USD 9 billion) (CAG India, 2021; IR, 2021). Prices and operational losses vary according to the nine coach classes. The NRP merges these coach classes into three groups and forecasts the number of passengers until 2050: long-distance air conditioned (LDAC), long-distance non-air conditioned, and suburban (MoR, 2020). Among these passenger groups, LDAC is assumed to be the wealthiest and best suited for price reform. Figure 13 forecasts the total losses from LDAC passengers. The avoided losses have been estimated, assuming a 2% increase in LDAC passenger fares every year, reaching INR 141 billion (USD 1.8 billion) by FY 2051.

**Figure 13.** Forecast nominal losses for LDAC passengers (INR billion), 2020–2050




Source: Authors' estimates from financial analysis.

Table 5 shows that the avoided loss in present value terms over the long term is INR 140 billion (USD 2 billion). This is equivalent to 7% of CFaR from falling coal freight revenues and reduces the overall CFaR by just 1%. An immediate and complete 100% cost-recovery of LDAC passengers can avoid INR 583 billion (USD 8.2 billion) in losses—but we do not recommend this course of action, given the likely negative social impacts. This is a conservative estimate, and faster reform is possible with large political capital and appropriate measures to ensure continued affordability. The assessment does not factor in passenger behavioural change, such as avoiding travel, switching to a lower class, or using alternate modes of travel.

**Table 5.** Net cash flow at risk after avoided losses from passenger price reform (INR billion), (2020–2050)

| | NPV (Avoided losses from LDAC price reform) | CFaR | CFaR % |
|---|---|---|---|
| Short term (2020–2030) | 30 | 584 | 20% |
| Medium term (2020–2040) | 87 | 1,478 | 23% |
| Long term (2020–2050) | 140 | 1,972 | 21% |

Source: Authors' estimates from financial analysis.

## Risk Mitigation Potential: Enhanced freight traffic

Shifting freight from road to rail is an important step in decarbonizing the transport sector. IR has made considerable investments toward dedicated freight corridors and improving the freight operations (IR, 2021). In the FY 2017 railway budget, IR introduced Mission Raftaar, which had, among others, the objective of doubling average freight speeds from 25 km/h to 50 km/h by 2022 (IR, 2016). Despite strategy assessments by the Railway Board, this target was not achieved, with average freight speeds still at 23.6 km/h in FY 2020 (CAG India, 2021; IR, 2018). In the NRP, a modelling exercise has been carried out to identify the railway's share of national freight under various scenarios. One of the scenarios considered is enhanced freight speeds reaching the same target of average freight speeds of 50 km/h by 2026 (MoR, 2020).

In Table 6, gross revenues have been estimated and adjusted to present value from various non-coal commodities. Average revenue rates from FY 2020 and forecasts by the NRP under BAU and enhanced freight speed scenarios are used (IR, 2021; MoR, 2020). Over the long term, the additional gross revenue from increased freight speeds is INR 3,644 billion (USD 51 billion) and is 12% by value of gross revenues in the SDS scenario. However, not all of this additional gross revenue would translate to net revenue increases due to expenses associated with increasing speeds.

**Table 6.** Gross revenue addition from non-coal freight through enhanced freight speeds for IR (INR billion), 2020–2050

| | NPV (Gross revenue, SDS) | NPV (Freight, BAU) | NPV (Enhanced freight) | Additional gross revenue | % Addition |
|---|---|---|---|---|---|
| Short term (2020–2030) | 16,118 | 7,378 | 8,772 | 1,393 | 9% |
| Medium term (2020–2040) | 24,464 | 13,913 | 16,732 | 2,819 | 12% |
| Long term (2020–2050) | 29,507 | 18,460 | 22,104 | 3,644 | 12% |

Source: Authors' estimates from financial analysis.

## Key Takeaways

### IR

- **Develop a roadmap to lease unused land for SPV.** To meet the target of setting up 20 GW of SPV through leasing land, IR is recommended to fast-track a feasibility assessment, identify regulatory support needed, and develop ownership and financing models for implementation.
- **Identify business opportunities in the clean energy transition to support passenger fares.** Passenger price reform is politically challenging and will not scale to cover the CFaR when done in a socially responsible, phased manner. This is not a strong risk mitigation strategy, and hence, there is a need to identify and capture economic gains from the clean energy transition away from coal.
- **Improve freight operations for non-coal commodities.** Operational improvements like enhancing freight speed can increase the market share of rail. Additional revenues from non-coal freight can considerably reduce financial risks.

### MoR

- **Commission the Railway Board to develop a coal phase-down risk mitigation plan.** The plan must focus on reducing dependence on coal freight and capturing economic gains from the clean energy transition.
- **Sustain efforts for passenger price reforms.** Despite the political-economy challenges, the MoR is recommended to continue to make efforts to reduce passenger price subsidies, such as incremental price hikes and targeting beneficiaries. Leaving it unchecked with falling freight revenues can result in a tremendous burden on the budget.

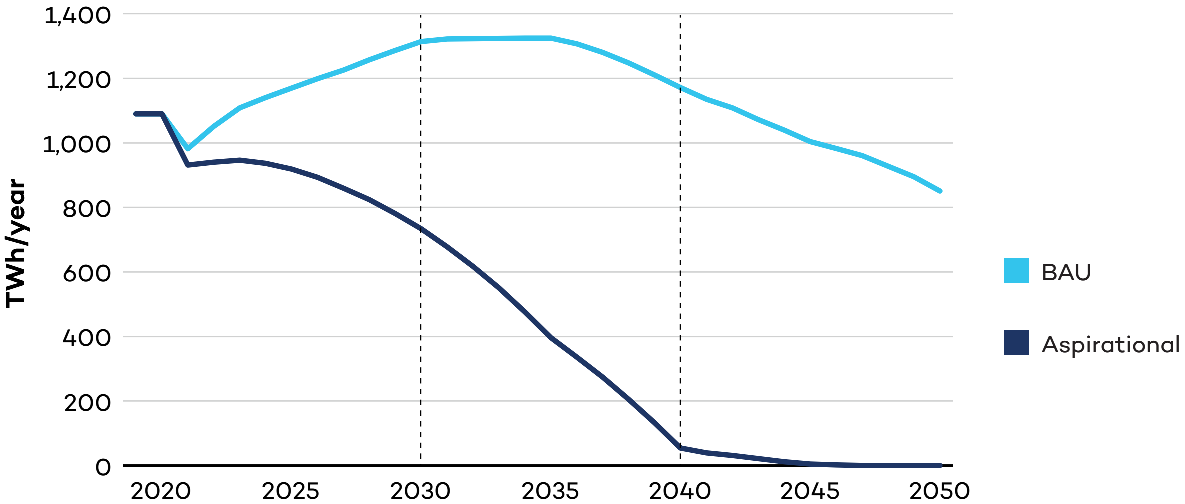
## 4.3 NTPC

NTPC's core business is power generation. As of 2021, coal accounts for 92% of its generation mix, and it owns or operates 54 GW of coal thermal power plants across India. In FY 2021, NTPC's coal consumption stood at 195 MT (NTPC, 2021a). As of 2022, NTPC accounts for approximately 27% of India's total installed coal power capacity, which stands at 204 GW (CEA, 2022a). Like other coal-intensive PSUs, IEA scenarios suggest that NTPC faces considerable risk in future years as the power system shifts from coal to renewable energy.

The government has set bold targets for clean energy: 450 GW of renewable power by 2030, up from around 113 GW (excluding hydro) as of the end of May 2022 (CEA, 2022b). In climate negotiations, there is an acknowledgement that coal will be phased down, but currently no explicit target or timeline exists. Changing cost dynamics for renewable energy also challenges the economic feasibility of the expansion of coal-based power projects. In FY 2021, solar power tariffs touched record low levels at INR 2 (USD 0.027) per kWh (USD 0.027/kWh), which is cheaper than even the variable cost of coal-fired power (Shah, 2021).

Figure 14 illustrates broad future scenarios for coal-based generation from 2020 to 2050, drawing on projections by the IEA. It shows BAU as broadly aligned with existing targets and an Aspirational pathway, as broadly consistent with net-zero by 2070. Under BAU, coal-based generation will peak by 2035, while under an Aspirational scenario, peaking has already taken place. The two scenarios diverge greatly in the medium and the long terms, where the Aspirational scenario assumes a much more rapid phase-down and a full phase-out by 2050. It must be observed that BAU is highly unlikely to depict actual future trends, and even the Aspirational scenario may underestimate the pace of future change, given expectations for the ratcheting up of climate ambition in the Paris Agreement framework and the need for coordinated global action to limit warming to no more than 1.5°C.

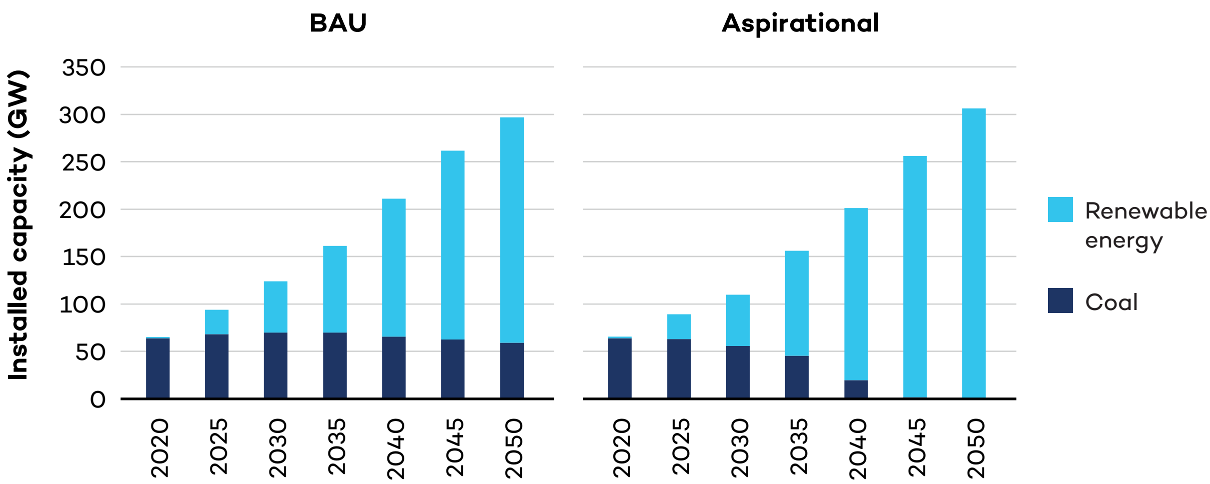
**Figure 14.** Pathways on national coal-based power generation (TWh/year), 2020–2050




Source: Authors' estimates based on GEM modelling.

As part of its short-term growth strategy, NTPC has declared its intent to become a 130 GW company with diversified fuel sources by 2032 (NTPC, n.d.). Recently, it also revised its renewable energy target, up from 30 GW to 60 GW by 2032, which requires about INR 2,500 billion (USD 33 billion) in investments (PTI, 2021; Singh, 2021). However, NTPC expects coal to continue dominating its portfolio until 2032 (NTPC, n.d.). Beyond 2032, Figure 15 illustrates how NTPC's portfolio might vary under the two scenarios, assuming it meets its 2032 renewable energy target and thereafter maintains its market share of national coal and renewable energy capacity. Under both scenarios, the demand for coal-based power will significantly decline, and there will be increased investments in renewable energy.

**Figure 15.** Forecast of NTPC's installed capacity mix in GW, 2020–2050



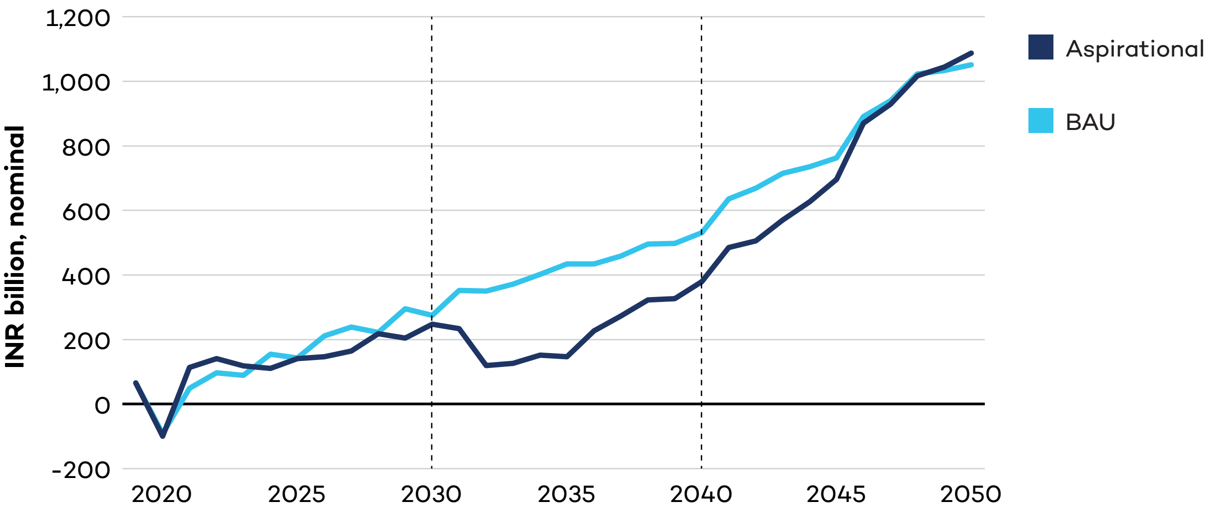

Source: Authors' estimates based on GEM modelling.

## Financial Risks

As shown in Figure 16, NTPC's cash flows were estimated from 2020–2050 across both scenarios, capturing both its coal and renewable energy business. Earnings per unit of power generation from coal and renewable energy were adjusted based on NTPC's annual financial statements and industrial benchmarks to arrive at the cash flow from operating activities. Volatility in initial years reflects actual data on impacts of COVID-19 (see Appendix B for full details).

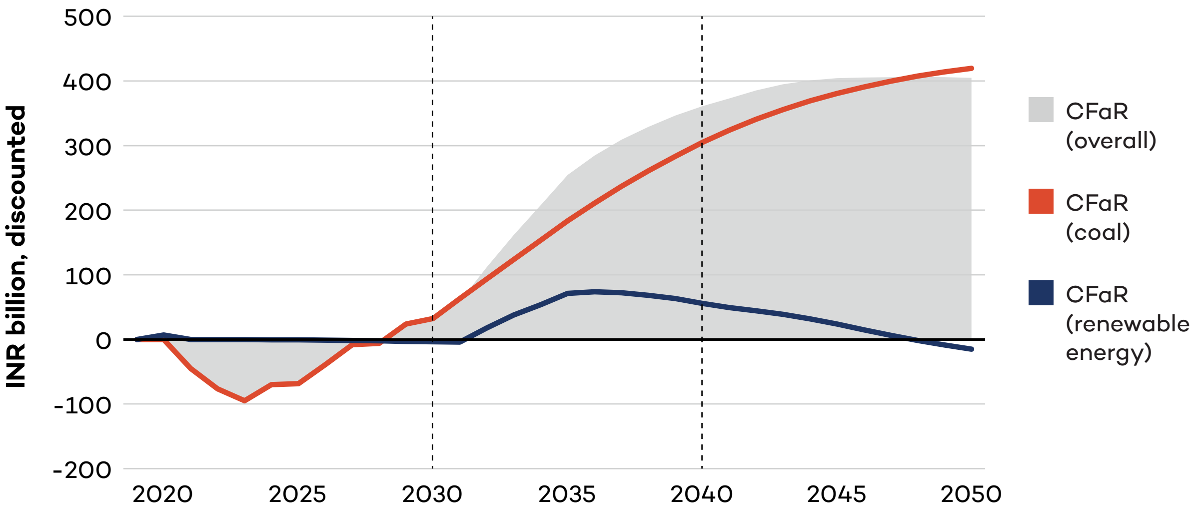
In the short term (2020–2030), under both scenarios, we anticipate that NTPC will follow its stated renewable energy target, and free cash flow will recover along with the economy and growth in power demand, climbing up to around INR 250 billion (USD 3.5 billion). In the medium term (2030–2040), however, under the Aspirational scenario, there is a significant loss in cash flow mainly due to lower demand for thermal power and investments in renewable energy.

**Figure 16.** Forecast nominal free cash flow (NTPC), 2020–2050




Source: Authors' estimates from financial analysis.

**Figure 17.** Cumulative discounted cash flow at risk for coal and renewable energy, 2020–2050




Source: Authors' estimates from financial analysis.

As seen in Figure 17, in present value terms, discounting at 12% per annum, the total CFaR over the long term is INR 404 billion (USD 5.7 billion). This corresponds to around 22% of NTPC's NPV in the BAU scenario (see Table 7). The biggest increment in risk is in the medium term, with CFaR going up to 12 times the value over the short term, primarily driven by falling plant load factors of coal power plants and the need for capital expenditure for ramping up renewable energy capacity. At current renewable energy ambition levels, it is only toward the end of 2050 that cash flows linked to renewable energy start mitigating the risk from coal. Given a 25-year lifetime of renewable energy projects, it can be expected that the later installations would continue to significantly contribute to revenue beyond the assessment period running to the 2070s. Over a 10-year period, from 2050 to 2060, the renewable fleet present in 2050 reduces CFaR through additional revenue of INR 51 billion (USD 0.7 billion) in current value.

**Table 7.** Financial risks to the coal-dependent business of NTPC, 2020–2050 (INR billion)

| | NPV (BAU) | NPV (Aspirational) | CFaR | % |
|---|---|---|---|---|
| Short term (2020–2030) | 754 | 725 | 29 | 4% |
| Medium term (2020–2040) | 1,426 | 1,065 | 361 | 25% |
| Long term (2020–2050) | 1,843 | 1,438 | 404 | 22% |

Source: Authors' estimates from financial analysis.

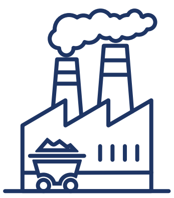
## Identified Diversification Actions

Recognizing this market imperative over the last few years, NTPC has diversified its portfolio into renewable energy, consultancy, power trading, training power professionals, and coal mining to strengthen its core business model of being primarily a thermal power generator (NTPC, 2021a).

To mitigate further risks, additional diversification strategies were identified through NTPC's statements and expert consultations.

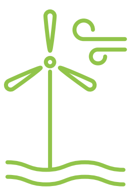
**Investing in battery storage:**

To capture the full benefits of the 60 GW of renewable energy by 2032, NTPC can invest in battery energy storage systems (BESSs). This investment can unlock new revenue streams by aiding in the integration of renewables and, in part, mitigate CFaR.



**Strategic decommissioning and repurposing of thermal power plants (TPP):**

Recent studies show that early retirement planning of TPPs can reduce the likelihood of worsening risks, and such planned decommissioning can lead to gross benefits from repurposing for three applications—solar energy, BESSs, and synchronous condensers (Jindal & Shrimali, 2022).



**Piloting emerging clean energy technologies like offshore wind:**

The Ministry of New and Renewable Energy has set a target of reaching 30 GW of offshore wind capacity by 2030 and is aiming to release the first offshore wind tender in the next 3–4 months (Buljan, 2022). Given the higher efficiency and stable generation profile of offshore wind projects, NTPC can become an early adopter to mitigate risks in the medium term. Since this technology is yet to reach the development stage, its risk mitigation potential has not been quantified.

## Risk Mitigation Potential: Investing in battery storage

As per CEA's optimal generation capacity mix for 2029–2030, India will need a capacity addition of 27 GW/108 GWh of battery storage to support grid stability. With higher variable renewable energy targets for 2032, BESSs can have multiple use cases for NTPC, ranging from storing surplus energy during low demand periods and optimally dispatching during peaks to the flexible operation of TPPs and providing ancillary services. They also reduce the demand for idle capacity reserved for balancing, which in turn enables the decommissioning and repurposing of TPPs.

When used for meeting peak demand, we see positive cash flows from BESSs from 2030 onwards. To model these, 4-hour battery storage was considered to meet the system flexibility requirement based on industry benchmark capital costs (Deorah et al., 2020). The analysis shows that by investing early in BESSs, NTPC can mitigate part of its medium- and long-term CFaR (2%–3%), as shown in Table 8. Studies also suggest that BESSs could become cheaper than both pithead and non-pithead coal power by 2030, which could further increase its mitigation potential as a diversification pathway (Shrimali & Jindal, 2021).

**Table 8.** Net cash flow at risk after avoided losses with BESSs for NTPC, 2020–2050 (INR billion)

| | NPV (BAU) | NPV (Aspirational) | CFaR | % |
|---|---|---|---|---|
| Short term (2020–2030) | 754 | 727 | 27 | 4% |
| Medium term (2020–2040) | 1,426 | 1,098 | 328 | 23% |
| Long term (2020–2050) | 1,843 | 1,497 | 345 | 19% |

Source: Authors' estimates from financial analysis.

## Risk Mitigation Potential: Strategic decommissioning and repurposing of TPPs

At the pan-Indian level, 54 GW of the current and mostly sub-critical coal capacity is estimated to be older than 25 years by 2030 and can be considered for retirement (Lolla, 2021). Out of this, the 13th National Electricity Plan shows that the CEA can consider 13.2 GW of NTPC's thermal capacity for retirement between 2022 and 2027 (CEA, 2018). The decommissioning of old plants is expected under both scenarios, with overall installed capacity falling.

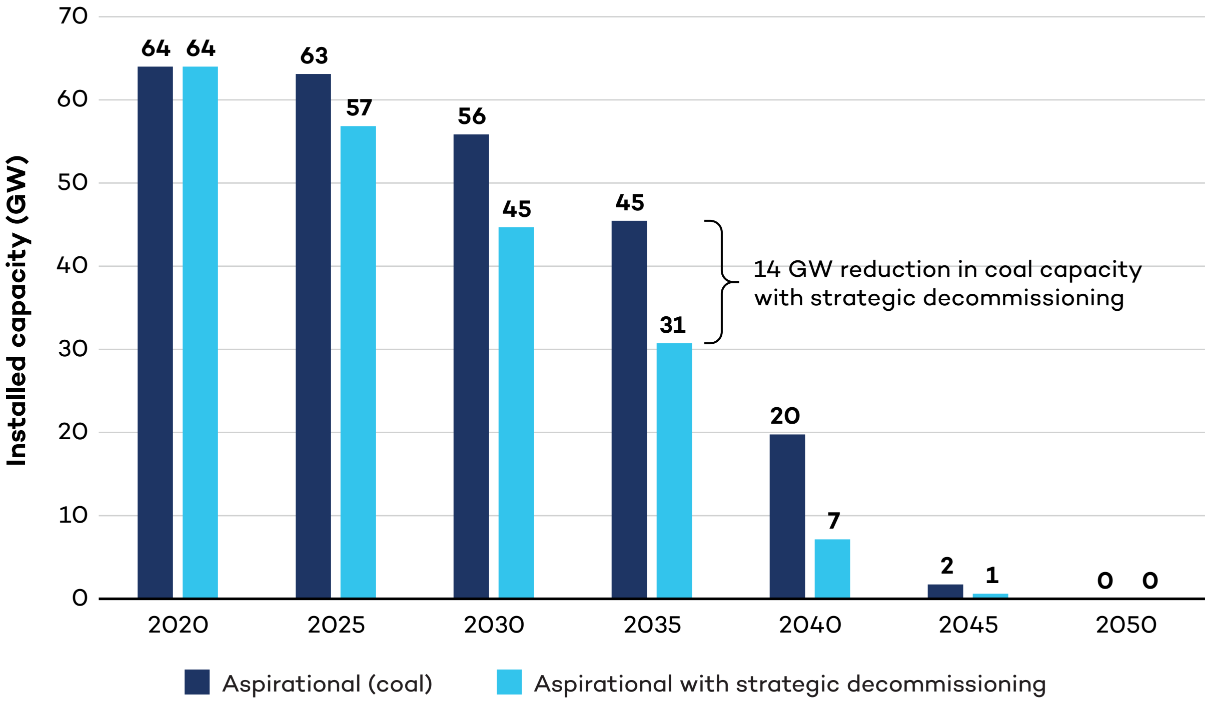
However, a comparison of national installed coal capacity and power generation from coal shows a significant reduction in overall utilization of the coal fleet in the medium and long terms. This brings added financial and technical risk to NTPC's coal business. In FY 2021, NTPC added 2.26 GW of new coal-based power projects, and another 11.8 GW is under construction (NTPC, 2021a, 2021b). These investments in new plants are at risk of becoming stranded assets as capacity utilization falls.

Further, the GoI issued guidelines allowing distribution companies to exit from power purchase agreements for central generating units that have completed 25 years of life (MoP, 2021). This contractual flexibility for distribution companies poses an additional risk for NTPC in the medium to long term as they increasingly shift to managing their demand in real time rather than through long-term contracts.

To counter these risks, we modelled a roadmap for the strategic decommissioning of NTPC's coal plants to maintain the current firm-level earnings per unit of power generation levels and the plant load factors of TPPs above the technical limit, in the range of 50%–60%. The results show that NTPC can raise ambition and accelerate the decommissioning process by about one third of its fleet, or 14 GW, by 2035 (see Figure 18). This process can start with inefficient, sub-critical, and older plants.

This strategic decommissioning will enable higher utilization of the remaining capacity, save on operation and maintenance expenses, and avoid the stranding of key assets and the likelihood of worsening risk. When combined with repurposing, this can lead to overall gross benefits (Jindal & Shrimali, 2022). However, research on repurposing is still evolving, and the firm-level benefits have not been modelled at this stage.

**Figure 18.** Roadmap for phasing down coal capacity for NTPC under mitigation scenarios (FY 2020–FY 2050)




Source: Authors' estimates based on GEM modelling.

## Key Takeaways

### NTPC

- **Meeting the existing renewable energy target of 60 GW by 2032 is imperative:** The current model builds on NTPC's stated target of 60 GW by 2032 and shows that, despite the existing target, the company faces significant transition risks in the long term. Therefore, to avoid added risks, NTPC must ensure that it takes all the necessary steps to meet these targets.
- **Short-term investments in TPPs can lead to significant transition risks in the medium and long terms:** Fresh investments in TPPs in the short term can have significant opportunity costs for NTPC, given the falling renewable energy tariffs. This investment should be instead channelled into financing greenfield renewable energy opportunities and increasing the flexibility of the existing fleet through BESSs.
- **Creating a decommissioning roadmap can maximize profitability and reduce systemic risk:** Phasing down and repurposing TPPs can unlock value by reducing operation and maintenance expenses on stranded assets. Further, the absence of a clear decommissioning roadmap also induces systemic risks for the energy system in the long term. Given its major role in India's electricity mix, NTPC, together with the MoP, must outline and communicate a clear roadmap to phase down its coal capacity to enable better planning for system operators.
- **Pilot new clean energy technologies and capture emerging value chains:** GoI's 2030 clean energy targets are creating several greenfield opportunities across technologies like offshore wind, green hydrogen, and e-mobility. NTPC should prepare detailed investment plans for such demonstration projects to enable state planning.

### MoP

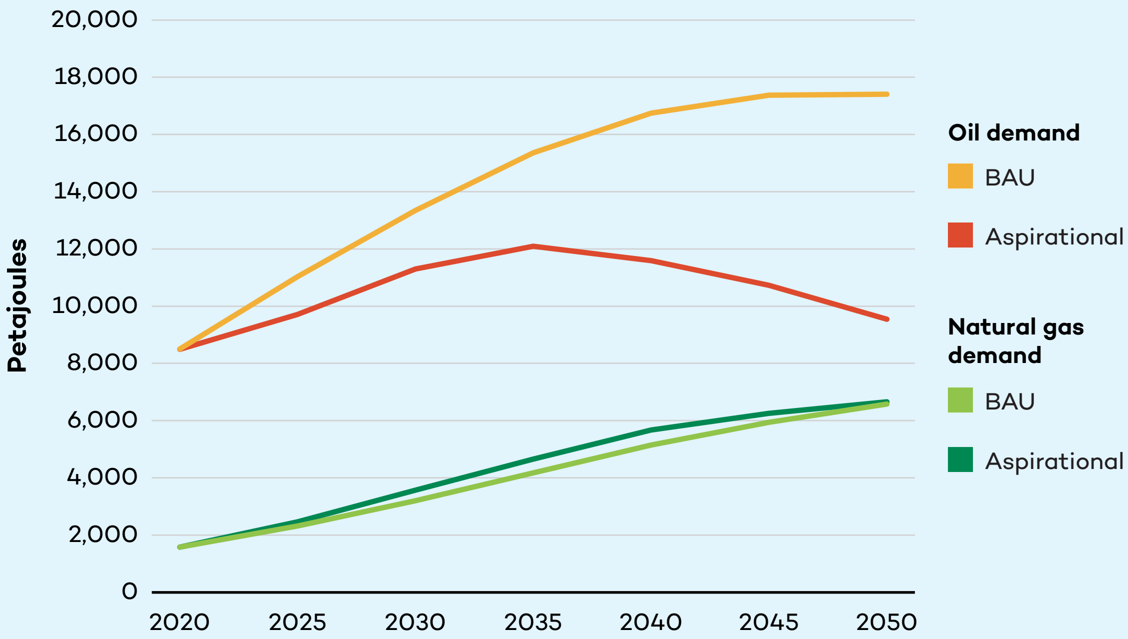
- **Commission coal phase-down planning and repurposing studies:** As stated earlier, early retirement planning of TPPs can unlock new value and lead to gross benefits for NTPC. As the nodal ministry governing decommissioning norms, the MoP can commission a detailed study for coal power phase-down to enable better system planning.
- **Continue with market reforms for renewable energy and enable strategic partnerships:** As a late market entrant in the renewable energy sector, NTPC can gain significantly through electricity market reform, strategic acquisitions, and partnerships with other PSUs to achieve its renewable energy targets. As its majority shareholder, the GoI through the MoP should play an active stewardship role in helping NTPC transition to an integrated energy company built on clean energy business models.

## Box 2. Energy transition risks for India's oil and gas PSUs

As shown in Figure 19, India's oil demand is expected to peak in 2047 under BAU, more than doubling current levels. However, under the Aspirational scenario, it peaks by 2037. This mirrors the IEA World Energy Outlook's SDS, which shows India's total oil demand decreasing from 4.4 million barrels per day (mbd) in 2020 to 4.1 mbd in 2050 (IEA, 2021b).

This trade-off between short-term growth and long-term risks is an important consideration for India's public sector oil refining companies, namely Indian Oil Corporation Ltd, Bharat Petroleum Corporation Ltd, Hindustan Petroleum Corporation Ltd, and Oil and Natural Gas Corporation. In FY 2023, together with the Gas Authority of India Ltd and Oil India Ltd, the six PSUs aim to increase capital expenditure by 7.4%, and state refiners plan to invest INR 2 trillion (USD 25 billion) by 2025 (PTI, 2022a; Reuters, 2021). The demand risk from oil consumption peaking in the 2030s before entering a gradual decline can create financial challenges for the refining sector. Out of India's total refining capacity of 5 mbd, estimates show that up to 430,000 barrels per day of refining capacity is "at risk" of underutilization through the 2030s and beyond (IEA, 2021a).

**Figure 19.** India's oil and natural gas demand (Petajoules), 2020–2050




Source: Authors' estimates based on GEM modelling.

Contrary to oil, natural gas demand is expected to increase under both scenarios, going up over 4 times by 2050 (see Figure 19). India is emerging as a fast-growing importer of gas, and government is actively pushing for new import terminals and transportation and distribution infrastructure (Muttitt et al., 2021). However, betting on natural gas remains risky. Over 22% of the demand under BAU by 2050 is expected to come from the power sector (IEA, 2021b). In reality, experts are skeptical of natural gas's future in power generation, with the CEA's optimal generation mix prioritizing batteries for grid balancing (CEA, 2020). The remaining gas demand comes from the transport and industrial sectors, where the government is also pushing for cleaner alternatives like electric vehicles and green hydrogen. Liquefied natural gas's near 50% import dependence threatens energy security and high emissions across its life cycle, questioning the paradigm of natural gas as a transition fuel (Jain, 2021).

In addition to demand and policy uncertainty, India's oil and gas PSUs face significant risks from price volatility. The global price of oil and gas is the primary factor in determining the economic viability of a reserve. The Russia–Ukraine war has shown that oil and gas prices will continue to be volatile in the coming years. In the short term, while demand growth ensures that the expected business performance of India's oil and gas PSUs will remain positive, increased volatility in prices and peaking of demand can create a risk of stranded assets in the long term (Jain, 2021). For Indian state refiners whose marketing margins are subject to government interventions, this can pose an additional financial risk.

Currently, there are no studies that quantify the value at risk or CFaR for oil and gas PSUs in India. The framework used in this study can further be used to conduct a detailed analysis of the oil and gas sector and explore potential diversification routes for renewables, electric vehicles, and green hydrogen, among others. This is particularly important because, unlike coal-dependent PSUs, investments in alternative clean energy technologies by oil and gas PSUs continue to remain marginal (Aggarwal et al., 2022). Such an analysis can help ramp up ambition and prepare PSUs better for the energy transition.

# 5.0 Recommendations

Our analysis indicates that this modelling approach effectively demonstrates that fossil fuel-dependent PSUs are prone to financial risks. These risks add up over time, and hence, there is a need for immediate action. Accordingly, six major cross-cutting recommendations for the PSUs are listed below. Their relevance extends beyond the three firms analyzed to include other fossil fuel-dependent PSUs in India and similar energy SOEs in emerging economies.

1. **Create a net-zero roadmap:** Meeting near-term demands, such as resolving coal shortages or keeping energy prices in check, is critical. However, decisions made now can have long-term consequences. A roadmap with interim targets for the firm, developed in consultation with relevant stakeholders, can become a guide for future decisions.
2. **Develop in-house estimates on business risks in the energy transition:** This analysis is based on simplified assumptions and publicly available information. However, firms are best placed to assess their own risks and opportunities, using this approach in combination with their own more precise internal data.
3. **Identify new clean energy business opportunities:** As markets emerge, new value chains are created. With their existing fossil fuel-based revenue streams and ability to raise capital at favourable rates, PSUs are well placed to become early adopters of clean energy.
4. **Set clean energy targets in proportion to existing risks:** Following the above two points, ambitions to develop clean energy businesses must be designed to match the potential scale and speed of the energy transition to comprehensively mitigate downside risks. This mitigation includes setting investment targets for clean energy and periodically revising ambition.
5. **Build strategic partnerships:** Develop partnerships to exchange expertise and invest in research and development. Inter-PSU contracts, such as purchase arrangements, can bring in new investors. Partnerships and acquisitions with smaller, innovative private firms can also help build internal capacity in new and emerging clean energy technologies.
6. **Make ambitions for the transition public:** Articulating specific and measurable targets and tracking progress through public disclosures can send market signals that further strengthen all of the above recommendations.

Our capstone recommendation is that PSUs, with support from their nodal ministries, can adopt the evidence-based approach used in this study to identify diversification strategies. This will future-proof these firms by continuing to bring revenues to the government, creating jobs, and sustaining their social value.

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# Appendix A. Green Economy Model Assumptions

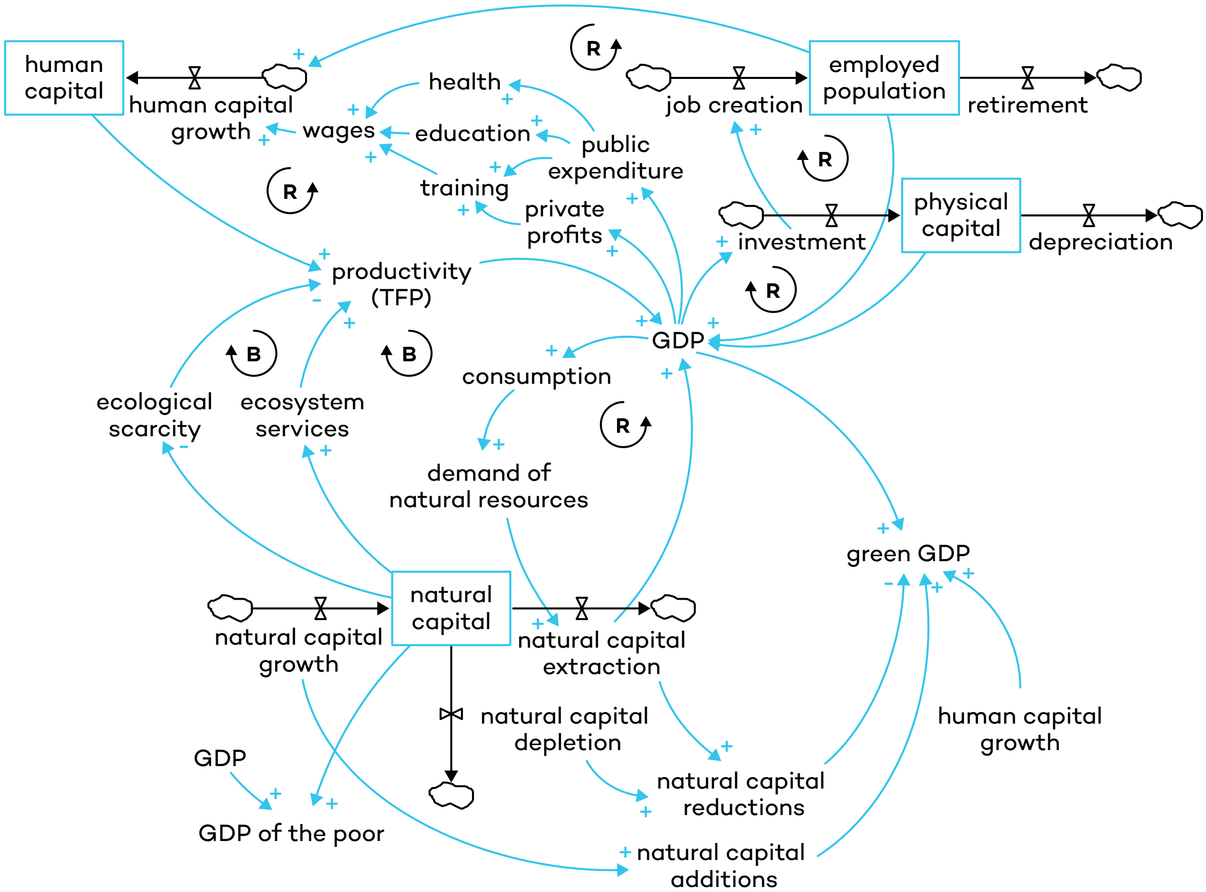
## A1. Overview of the Model and Methodology Used

The green economy model (GEM) was developed using system dynamics (SD) as the underlying methodology and serves primarily as a knowledge integrator. SD is a form of computer simulation modelling and was originally conceived to facilitate a more comprehensive approach to development planning, especially when it comes to analyzing the medium- to long-term impacts of development (Forrester, 2002; Meadows, 1980, p. 1; Randers, 1980; Richardson & Pugh, 1981). SD models use differential equations for simulating "what if" scenarios, whereby stocks and flows are explicitly represented and allow for capturing non-linearities that emerge as a result of their interactions over time. The methodology provides the flexibility to integrate equations from optimization and econometric modelling approaches. The purpose of SD is to inform policy formulation by forecasting policy outcomes (both desirable and undesirable), leading to the creation of a resilient and well-balanced strategy rather than attempting to generate precise predictions or optimize performance for a specific indicator (Probst & Bassi, 2014; Roberts et al., 1983).

GEM includes four key capitals (physical, human, social, and natural) that are interconnected via explicit causal linkages that allow the representation of feedback loops (reinforcing or balancing). GEM further allows for simulating the implementation of various policy interventions that either (i) strengthen growth (i.e., reinforcing loops) or (ii) curb change (e.g., by strengthening balancing loops). In this specific study, GEM was used to analyze the decarbonization pathways of the energy sector based on World Energy Outlook forecasts (IEA, 2021b). The World Energy Outlook forecasts are further informed by the latest findings of the India Energy Outlook (IEA, 2021a). The analysis of energy-related interventions enables an assessment of the system-wide outcomes of the simultaneous implementation of various intervention options within and across sectors for social, economic, and environmental indicators. In addition to the simulation of energy-related policies, the GEM structure was expanded to also include coal production, imports, exports, and related transport requirements. This allows an assessment of the impacts of energy policy within and across sectors for social, economic, and environmental indicators over time.

Figure A1 shows the generalized underlying structure of GEM, including the four capital stocks and their interlinkages. This underlying model was used as a starting point for the creation of the GEM-India model. This diagram shows how the four capital stocks are interconnected and visualizes the connections through which they contribute to shaping future trends across social, economic, and environmental indicators. Feedback loops marked with an (R) constitute reinforcing feedback loops, which maintain and drive economic growth and social development. The underlying assumption is that growth and development are enabled by the availability of natural capital, which can constrain or curb growth if not properly managed. This dynamic is captured through balancing loops, marked with a (B), which essentially represent the limits of growth in the system.

**Figure A1.** Causal loop diagram representing the main variables and feedback loops of GEM




## A2. GEM for India

Green economic modelling and establishing priorities for cross-sectoral analysis is a process of co-development and co-creation. To ensure that the modelling outcomes are useful for informing decision making, GEM is typically co-developed with local experts. For this assessment, GEM was customized to the Indian context with sectoral experts from the International Institute for Sustainable Development.

The GEM-India model developed includes (1) a macroeconomic module and (2) several sectoral models (Golechha et al., 2022). For this analysis, particular attention was paid to the calibration of energy demand and supply—and related emissions—to ensure that GEM and the scenarios simulated were calibrated to reproduce the Stated Policies Scenario and Sustainable Development Scenario (SDS) of the *World Energy Outlook 2021*. An accounting of emissions in additional sectors—such as agriculture and infrastructure—are needed to carry out an in-depth assessment of sectoral performance. The interconnectedness of the modules unlocks the potential to generate valuable information for the development of sectoral green economy strategies—in this instance, related to energy consumption and coal-related variables. The macroeconomic module allows us to test the cross-sectoral coherence of the sectoral interventions proposed (e.g., will side effects emerge when sectoral interventions are implemented?) and to assess the outcomes of policy interventions at the national level (e.g., their contributions to GDP and employment creation). The key assumptions used in the model are summarized in Table A1.

**Table A1.** Key assumptions and parameters of the GEM–India

| Indicator | Type of data | Source(s) |
|---|---|---|
| **Key model drivers** | | |
| Population (past and future) | Time series | World Population Prospects, 2021; United Nations, n.d. |
| Real GDP and real GDP growth | Time series | World Bank, n.d. |
| Future GDP growth (short term) | Time series | International Monetary Fund, 2021 |
| Future GDP growth (long term) | None | Forecasted endogenously based on model parameterization |
| **Energy demand** | | |
| Past trends | | |
| National energy balance of India | Time series | Ministry of Statistics and Programme Implementation [MOSPI], 2011–2022 |
| Future trends | | |
| Final energy consumption by sector and fuel | Time series | International Energy Agency (IEA), 2021b |
| Total carbon dioxide equivalent emissions from energy, by fuel and sector | Time series | IEA, 2021b |
| **Power generation** | | |
| Electricity generation by type of capacity | Time series | IEA, 2021b |
| Installed capacity, by technology | Time series | IEA, 2021b |
| Capital cost per MW of capacity | Time series | IEA, 2021b |
| Operation and maintenance cost per MW of capacity | Time series | IEA, 2021b |
| Load factor by type of capacity | Time series | IEA, 2021b |
| **Coal production and transport** | | |
| Domestic coal production | Time series | NITI Aayog, 2021 |
| Coal use for power generation | Time series | MOSPI, 2021 |

| Indicator | Type of data | Source(s) |
|---|---|---|
| Coal use for non-power purposes | Time series | Ministry of Coal, 2021 |
| Residual coal use for non-energy purposes | Time series | MOSPI, 2021; NITI Aayog, 2021 |
| Coal imports | Time series | NITI Aayog, 2021 |
| Coal transport with national railways | Time series | Indian Railways, 2021; Ministry of Railways, 2020 |
| **Air pollution** | | |
| Air pollutants per TJ of final energy<br>(11 pollutants, by fuel type and sector) | Constant | Stockholm Environment Institute, n.d. |
| Air pollutants per TJ of electricity generated<br>(11 pollutants, by fuel and technology) | Constant | Stockholm Environment Institute, n.d. |

# Appendix B. Financial Analysis

## B1. Overview of the Model and Methodology Used

To estimate cash flow at risk (CFaR), we adjusted available financial data from company financial statements to enable a calculation of financial flows on a per-unit-of-coal basis (Coal India Limited [CIL], 2011–2020; NTPC, 2011–2020; Railway Board, 2011–2020). Table B1 provides a generic methodology adopted for financial modelling, which has been suitably modified based on data availability to adapt to the business models for each of the actors (CIL, NTPC, Indian Railways [IR]) in subsequent tables.

For this analysis, first, we have assumed that the impacts on revenues and costs are largely proportional to GEM outputs. Next, earnings before interest, taxes, depreciation, and amortization (EBITDA) give a snapshot of net income before accounting for other factors, such as interest payments, taxes, and depreciation of assets. This helps to provide a clearer perspective on the operational performance of the firm. The use of the compound annual growth rate (CAGR) for estimating future projections on some key variables, such as EBITDA, operating cash flow (OCF), and capital expenditure (CAPEX) is based on the rationale that past trends are likely to continue. CAGR also evens out the ups and downs in growth over a time period across market changes.

**Table B1.** Generic methodology for financial modelling used in this study

| Steps | Activity | Parameter | Key variables | Period | Source |
|---|---|---|---|---|---|
| **Compilation of relevant data (Steps 1–7)** | | | | | |
| 1 | Compilation | Coal production/coal transportation/ coal-based generation | Price, quantity | 2010–2019 | Annual financial statements |
| 2 | Compilation | EBITDA | Revenue, Costs | 2010–2019 | Annual financial statements |
| 3 | Compilation | Interest, taxes, depreciation and amortization | - | 2010–2019 | Annual financial statements |
| 4 | Compilation | Net Income = EBITDA-Interest-Taxes-Depreciation and Amortization | Net Income | 2010–2019 | Annual financial statements |
| 5 | Compilation | Changes in working capital | - | 2010–2019 | Annual financial statements |
| 6 | Compilation | OCF | - | 2010–2019 | Annual financial statements |

| Steps | Activity | Parameter | Key variables | Period | Source |
|---|---|---|---|---|---|
| 7 | Compilation | CAPEX | - | 2010–2019 | Annual financial statements |
| **Estimation of financial metrics (Steps 8–13)** | | | | | |
| 8 | Input from GEM | Coal production/coal transportation/ coal-based generation | Price, quantity | 2020–2050 | GEM-India |
| 9 | Estimation | EBITDA | Net Income | 2020–2050 | CAGR Method (using Input from Step 4) |
| 10 | Estimation | OCF | - | 2020–2050 | CAGR Method (using Input from Step 6) |
| 11 | Estimation | CAPEX | - | 2020–2050 | CAGR Method (using Input from Step 7) |
| 12 | Estimation | Free cash flows = OCF-CAPEX | - | 2020–2050 | - |
| 13 | Estimation | Net present value (NPV) of FCF. CFaR | - | 2020–2050 | - |

## B2. Methodology for CIL

As summarized in Table B2, for CIL, we started from the following per tonne of coal (INR/t) data projections for the years 2020 to 2050 to derive an adjusted EBITDA (INR/t) *(EBITDAadj)*, ratio of OCF to EBITDA (OCF/EBITDA) (%) and planned CAPEX (billion INR).

Next, based on GEM results for coal demand and assumptions on CIL's share of domestic supply, we derived the volume of CIL coal production (in MT). We multiplied this value by the adjusted EBITDA to get EBITDA in billion INR:

$$EBITDA = Coal\ Production_t \times EBITDA_{adj}$$

We multiplied this EBITDA by OCF/EBITDA to get the operating Cash Flow (OCF). Next, we calculate the free cash flow expected (FCFE) by subtracting CAPEX from OCF.

$$FCFE = EBITDA \times OCF/EBITDA - (capex)$$

FCFE for the period 2020–2050 was then brought to present value using a discount rate of 12%, and CFaR was calculated by subtracting FCFE under BAU from that under Aspirational:

$$CFaR = FCFE_{BAU} - FCFE_{Aspirational}$$

**Table B2.** Methodology for financial modelling for CIL

| Steps | Activity | Parameter | Key variables | Period | Source |
|---|---|---|---|---|---|
| 1 | Compilation | Coal production | Price, quantity | 2010–2019 | Annual financial statements of CIL |
| 2 | Compilation | EBITDA | Revenue, Costs | 2010–2019 | Annual financial statements of CIL |
| 3 | Estimation | EBITDA intensity (INR/tonne) | - | 2010–2019 | EBITDA/ Coal production |
| 4 | Compilation | OCF | - | 2010–2019 | Annual financial statements of CIL |
| 5 | Estimation | OCF intensity (OCF/EBITDA) | - | 2010–2019 | OCF/EBITDA |
| 6 | Compilation | CAPEX | - | 2010–2019 | Annual financial statements of CIL |
| 7 | Obtained (from GEM Model) | Coal production | Price, quantity | 2020–2050 | GEM Model |
| 8 | Estimation | EBITDA intensity (INR/tonne) | - | 2020–2050 | CAGR Method |
| 9 | Estimation | EBITDA | - | 2020–2050 | EBITDA = EBITDA intensity x coal production |
| 10 | Estimation | OCF intensity (OCF/EBITDA) | - | 2020–2050 | CAGR method |
| 11 | Estimation | OCF | - | 2020–2050 | OCF = OCF Intensity x EBITDA |
| 12 | Estimation | CAPEX | - | 2020–2050 | CAGR method |
| 13 | Estimation | Free cash flows | - | 2020–2050 | FCF = OCF -CAPEX |
| 14 | Estimation | NPV, CFaR | - | 2020–2050 | |

## B3. Methodology for IR

As summarized in Table B3 for IR, to estimate CFaR, we focus on compiling EBITDA directly and bring it to NPV. Given no interest payments and taxes related to IR in this analysis, EBITDA equated to OCF. Additionally, we assumed that IR would not undertake additional CAPEX during the study period and that OCF would then also become FCFE.

We started from the coal transported to power plants in tonnes and obtained per tonne of coal (INR/t) data projections for the years 2020 to 2050, which forms the adjusted EBITDA (INR/t).

Based on GEM results for coal demand and assumptions on IR's share of coal transported, we derived the volume of coal transported by IR (in MT). We multiplied this value by the adjusted EBITDA to get EBITDA in billion INR:

$$EBITDA = Coal\ Transportation_t \times EBITDA_{adj}$$

EBITDA for the period 2020–2050 under BAU and Aspirational scenarios were then brought to present value using a discount rate of 12% and CFaR was calculated by subtracting EBITDA under BAU from that under Aspirational:

$$CFaR = EBITDA_{BAU} - EBITDA_{Aspirational}$$

**Table B3.** Methodology for financial modelling for IR

| Steps | Activity | Parameter | Key variables | Period | Source |
|---|---|---|---|---|---|
| 1 | Compilation | Coal transported to power plants | Price, Quantity | 2010–2019 | Annual financial statements of IR |
| 2 | Compilation | EBITDA | Revenue | 2010–2019 | Annual financial statements of IR |
| 3 | Estimation | EBITDA Intensity (INR/tonne) | - | 2010–2019 | EBITDA/ Coal transported |
| 4 | Obtained (from GEM) | Coal transported to power plants | Price, Quantity | 2020–2050 | GEM |
| 5 | Estimation | EBITDA Intensity (INR/tonne) | | 2020–2050 | CAGR method |
| 6 | Estimation | EBITDA | | 2020–2050 | EBITDA = EBITDA intensity x coal transported |

## B4. Methodology for NTPC

As summarized in Table B4, for NTPC, a similar approach was used but using kilowatt-hours (KWh) of electricity produced instead of coal volume produced as input to the financial modelling for both coal-based generation capacity and renewable energy capacity. Accordingly, we computed adjusted EBITDA (INR/KWh), ratio of OCF to EBITDA (OCF/EBITDA) (%) and planned CAPEX (billion INR) for both coal and renewable energy separately.

Based on GEM results for coal-based generation projection and NTPC planned capacity addition for 2030, we derived the coal-based generation and renewable energy generation (in KWh). We multiplied this value by the adjusted EBITDA to get EBITDA in billion INR for both coal and renewable energy separately:

$$EBITDA = Generation_{KWh} \times EBITDA_{adj}$$

We multiplied this EBITDA by OCF/EBITDA to get the operating cash flow (OCF). Next, we calculated the FCFE by subtracting CAPEX from OCF. FCFE was computed for both coal and renewable energy capacity separately and then summed up for NTPC as a whole.

$$FCFE = EBITDA \times OCF/EBITDA - (capex)$$

FCFE for the period 2020–2050 was then brought to present value using a discount rate of 12% and CFaR was calculated by subtracting FCFE under BAU scenario from that under Aspirational Scenario:

$$CFaR = FCFE_{BAU} - FCFE_{Aspirational}$$

**Table B4.** Methodology for financial modelling for NTPC

| Steps | Activity | Parameter | Key variables | Period | Source |
|---|---|---|---|---|---|
| 1 | Compilation | Coal-based generation, capacity | Quantity, Capacity | 2010–2019 | Annual financial statements of NTPC |
| 2 | Compilation | EBITDA | Revenue, Costs | 2010–2019 | Annual financial statements of NTPC |
| 3 | Estimation | EBITDA Intensity (INR/KWh) | - | 2010–2019 | EBITDA/ Coal-based generation |
| 4 | Compilation | OCF | - | 2010–2019 | Annual financial statements of NTPC |
| 5 | Estimation | OCF intensity (OCF/ EBITDA) | - | 2010–2019 | OCF/EBITDA |

| Steps | Activity | Parameter | Key variables | Period | Source |
|---|---|---|---|---|---|
| 6 | Compilation | CAPEX | - | 2010–2019 | Annual financial statements of NTPC |
| 7 | Obtained (from GEM Model) | Generation | Coal generation, renewable energy generation | 2020–2050 | GEM |
| 8 | Compilation | Installed capacity | Total, coal, renewable energy | 2020–2050 | GEM |
| 9 | Estimation | EBITDA intensity (INR/Unit) | EBITDA intensity<br>Coal/ renewable energy | 2020–2050 | CAGR Method |
| 10 | Estimation | EBITDA | EBITDA<br>Coal/ renewable energy | 2020–2050 | EBITDA = EBITDA intensity × generation |
| 11 | Estimation | OCF intensity | OCF<br>Coal/renewable energy | 2020–2050 | CAGR Method |
| 12 | Estimation | OCF | OCF Coal/ renewable energy | 2020–2050 | OCF = OCF Intensity × EBITDA |
| 13 | Estimation | CAPEX | CAPEX<br>Coal/ renewable energy | 2020–2050 | CAGR Method |
| 14 | Estimation | Free cash flows | - | 2020–2050 | FCF = OCF -CAPEX |
| 15 | Estimation | NPV, CFaR | - | 2020–2050 | |

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