Working paper

The Indian financial sector's exposure to coal-related stranded asset transition risks

Implications for financial institutions and the Reserve Bank of India

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Abstract

India proposes to phase-down coal and switch to zero-carbon electricity, especially solar and wind, over the coming decades. This analysis uses publicly available data, Indian and international models and company reports to estimate the transition risks to Indian financial institutions from climate transition scenarios. There will be a sharp rise in underutilised coal assets even in business as usual scenarios within a decade. This will cause financial stress to power companies, DISCOMS and financial institutions. This analysis should inform RBI and financial institutions seeking to understand and manage these risks

PARTNERING FOR ACCELERATED CLIMATE TRANSITIONS

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Acronyms

ABT	Availability-Based Tariff
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CERC	Central Electricity Regulatory Commission
CO_2	carbon dioxide
CSEP	Centre for Social and Economic Progress
DISCOM	(state-owned electricity) distribution company
DONG	Danish Oil and Natural Gas
DT	Delayed Transition (NGFS scenario name)
EPS	Electric Power Survey
EPS	Energy Policy Simulator (WRI)
EU	European Union
FI	financial institution (bank/NBFC)
GCAM	Global Change Assessment Model
GDP	gross domestic product
GEM	Global Energy Monitor
GW	gigawatt
GWh	gigawatt hour
IAM	integrated assessment model
IEA	International Energy Agency
IESS47	(Niti Ayog's) Indian Energy Security Scenarios to 2047
IESS47 NZ	(Niti Ayog's) net zero by 2070 Indian Energy Security Scenario to 2047
JGCRI	Joint Global Change Research Institute
MOSPI	Ministry of Statistics and Programme Implementation
NBFC	non-bank financial corporation
NDC	Nationally Determined Contributions (NGFS scenario name)
NEP	National Electricity Plan
NZ	Net Zero by 2050 (NGFS scenario name)
NGFS	(central banks and supervisors) Network for Greening the Financial System
PIER	Perspectives in Indian Energy based on Rumi

PFC	Power Finance Corporation (of India)
PLC	plant load factor
PV	(solar) photovoltaic
RE	Regulated Entity
RBI	Reserve Bank of India
TCFD	Taskforce for Climate-Related Financial Disclosures
TWh	terawatt hour
UK	United Kingdom
US	United States
WRI	World Resources Institute

Executive summary

This working paper is intended to support the Reserve Bank of India (RBI) and the financial institutions that it regulates in their accelerating efforts to identify and manage prospective financial sector risks emerging from the energy transition.

Financial institutions in India and all over the world have stated that they lack the data, methods and knowhow to evaluate their transition risk exposure, and therefore need more analytical work and guidance. There are indeed gaps and ambiguities in data, and methodological challenges. But it is also true that the Indian energy sector has extensive publicly available data, sophisticated open-access energy models and projections produced by government and independent researchers that can inform decision-making, with sufficient guidance and capacity-strengthening. By assessing transition risks associated with lending to thermal power plants and the associated supply chains, this working paper illustrates the types of analysis that can be performed using publicly available data – and underscores the urgency of a rapid but orderly phase-down of coal-fired power generation to manage the transition and physical risks of climate change.

India aims 'to achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, with the help of transfer of technology and low-cost international finance' (Government of India, 2022), and subsequently to achieve net zero emissions by 2070. At present, 70% of electricity generation is generated from coal. Coupled with the need to massively expand power supply, it is clear that India is anticipating extraordinary expansion of renewable electricity over the next six years and beyond, especially solar photovoltaic (PV).

The growth of solar will pose a serious challenge to the viability of coal-fired power plants, as solar PV will displace these plants during daylight hours, resulting in lower usage than anticipated by lenders, owners and operators. Plants incapable of ramping up and down may no longer be able to operate at all. India's coal plants are still relatively young, and their capital costs have not yet amortised, and low utilisation rates will reduce the revenues needed to pay down capital costs. However, this simple picture is complicated by the diversity of contractual and tariff arrangements, which mean that India's state-owned electricity boards often face perverse incentives to favour less energy-efficient coal-fired power plants. Thus, the concentration of transition risks is not straightforwardly related to the age or carbon efficiency of a plant.

In this working paper, we develop and compare electricity demand and the associated fuel mix under three scenarios. Because these are rooted in the global scenarios developed by the Network for Greening the Financial System (NGFS), an alliance of central banks and financial supervisors, they are given the same names: 'Nationally Determined Contributions (NDC)', 'Net Zero 2050 (NZ)' and 'Delayed Transition (DT)'. We then adapted them to the Indian context using national energy models and based on interviews with domestic experts. We combined these scenarios with asset-level data on the vintage and capacity of India's coal fleet to model the plant load factors, and thus estimate the current and future value of coal power stations in each scenario. Our approach also allowed us to calculate the aggregate value of 'stranded' coal assets.

In the NDC scenario, we find that installed capacity of coal dips but then grows somewhat as wind reaches its annual installation cap. In the Net Zero and Delayed Transition scenarios, the annual installation cap is lifted; as a result, no new coal-fired power plants need to be built after the 2030s.

The average plant load factor of coal is already low, at 56.6% (the normative loading is 85%). In the NDC scenario, it drops to 44% by 2031, owing to the decline in demand during daylight hours. The average plant load factor drops below 20% in the same year in the NZ scenario, and below 10% by 2035. However, the plant load factor varies considerably between power plants. In particular, the growth of solar will mean that daily demand for coal power experiences massive swings as it is needed to fill gaps from solar. Coal power plants incapable of ramping up and down rapidly in response will have difficulty remaining in operation.

We calculate the residual value of India's coal-fired power stations to be ₹11 lakh crore ($131bn), roughly four times the annual gross value added by the electricity sector. In addition, there are assets worth ₹3.2 lakh crore ($38.1bn) in coal supply chains, particularly mines, railways and ports.

Our analysis finds a sharp rise in underutilised coal assets in the NDC scenario, from ₹3.9 lakh crore ($46.5bn) in 2026 to ₹8.1 lakh crore ($96.5bn) by 2047 as newer coal plants come online, through hitting constraints in wind and solar additions. In the NZ scenario, the value of these 'stranded' coal assets peaks at ₹5.5 lakh crore in 2027 ($65.5bn) as the last coal-fired plant currently in construction starts operation, but quickly drops as new investment in coal ceases and the problem of stranded coal assets diminishes. For comparative purposes, RBI's most recent estimate of the current level of non-performing loans is ₹1.3 lakh crore ($15.5bn) mainly owed to public sector banks (RBI, nd).

Owners of these underutilised assets will still have to repay their capital costs but will see their revenues decline. If their coal-fired power plants are not able to operate flexibly or have less favourable contractual arrangements with DISCOMs (state-owned electricity distribution companies), they would rationally be retired ahead of schedule though political considerations might mitigate against this outcome.

The projected reduction in utilisation rates of existing coal capacity is a major source of financial risk to lenders to thermal power plants, even in the most conservative NDC scenario.

A critical question concerns how transition risks will be borne among key stakeholders: power plant owners, their financiers, the primary re-financier (Power Finance Corporation, PFC), DISCOMs and consumers. Others are indirectly exposed to transition risks: for example, rail passenger fares are heavily subsidised by coal freight. For the most part, we find that thermal power companies are insulated from transition risks because two-part tariff agreements oblige DISCOMs to pay fixed costs regardless of whether power is scheduled. This transfers the risk of stranded assets to the DISCOMs themselves, and thus to the state governments that own them. Such arrangements also heighten the risks of an unjust transition, whereby lower-income groups consuming electricity or travelling by rail bear higher costs when using these services; higher taxes as state governments absorb power sector losses; and greater climate impacts owing to the delayed nature of the energy transition.

A coordinated policy response is essential to ensure a rapid but orderly phase-down of coal-fired power while meeting India's growing demand for electricity.

The RBI has an important role to play in:

- developing and supplying scenarios with sufficient regional and temporal granularity to support financial sector planning and decision-making
- suggesting that financial institutions undertake long-term static balance sheet analysis that captures multiple factors that affect exposure to transition risk, such as the average age and expected lifespan of a power plant, the contractual arrangement with the relevant DISCOM, and its ability to ramp up and down quickly
- suggesting that financial institutions, particularly the PFC, engage systematically with borrowers in the coal supply chain (generators, DISCOMs, Coal India and Indian Railways) to carefully plan and manage the decommissioning of inefficient or unused plants in a timely and just way.

Other actors also have important roles to play in minimising the transition risks facing the financial sector as coal declines in India. DISCOMs will need to review and rationalise off-taker contract arrangements between generators and customers, providing financial packages to exit from contracts with perverse incentives where necessary. State governments will need to reform electricity subsidies to maintain low costs for households while incentivising the investments needed for a lower-carbon, lower-cost power system. The central government and state governments with high concentrations of coal activities should work closely with affected groups – workers, communities, financiers, asset owners and operators – to plan and implement just transitions. Far-sighted and joined-up action is essential to minimise the adverse impacts of the energy transition, advancing justice and sustaining macro-financial stability despite the disruptive impacts of climate change and technological innovation.

Though non-bank financial corporations, like the PFC, are not used to playing this role, they could help manage transition risks by:

- reviewing and rationalising off-taker contract arrangements between generators and customers and financial packages to exit from contracts with perverse incentives, such as maintaining inflexible old thermal plants in operation

- developing and financing a Just Transition package of measures to create alternate employment opportunities in mining communities
- funding innovation in DISCOMs to hasten the adoption of decentralised electricity generation and vehicle-to-grid bidirectional flows of power between customers and DISCOMs.

These are not the primary responsibility of a financial institution, but the financial institution can be an enabling financial partner in this transition. Transition is not always a risk; it can be an opportunity, and financial institutions can help seize it.

1 Introduction

1.1 Background

India is seeking to become a developed economy by 2047. In parallel, it is grappling with the risks that climate change poses to sustaining and securing its development gains, and the role that it can play in limiting the extent of global warming. Accordingly, the central government set a target 'to achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, with the help of transfer of technology and low-cost international finance' as part of the 'long-term goal of reaching net-zero by 2070' (Government of India, 2022).

India is on track to achieve its near-term climate goal: 45.13% of generation capacity in July 2024 was from non-fossil fuel sources.[1] This is an extraordinary achievement given the expansion of supply to keep pace with India's economic and population growth and redress historic infrastructure deficits. The renewables boom is a testament to the enabling environment for clean energy (especially solar) that India has created, as well as the tumbling prices of these technologies (Birol and Kant, 2022).

At the same time, India's near-term target is not compatible with limiting warming to 1.5°C (Climate Action Tracker, 2024). In addition to expanding clean power, the International Energy Agency (IEA, 2023) finds that reaching net zero energy systems by mid-century[2] demands no new unabated coal-fired power plants from 2021 and the retirement of the least efficient plants by 2030. Yet the average age of India's coal-fired power plants was only 13 years in 2021 (IEA, 2021) and much of the infrastructure servicing power production – coal mines, ports and railways – has been built equally recently or indeed is still in construction. Public financial support for energy still favours fossil fuels over renewables (Raizada et al., 2024).

Today, although nearly 50% of installed capacity is renewable, 73.1% of India's power in 2022–2023 still came from coal and gas (CEA, 2024). This has to be scaled down rapidly over the coming decades if the country is to meet its climate ambitions. Any accelerated phase-down or phase-out of coal will have financial consequences for the companies that developed and financed the coal infrastructure, given the expected long operational life of the facilities. These are collectively known as transition risks, which arise as a result of new policies or regulations, technological innovation or changing consumer demands and behaviours during the transition to clean

1 https://cea.nic.in/dashboard/?lang=en (accessed 13 September 2024).

2 Decarbonisation of the energy sector is a precondition and enabler for decarbonisation of other sectors, such as buildings, industry and transport. Therefore, the energy sector needs to reach net zero before the rest of the economy.

economies.[3] Appendix D presents a description of transition risks and stranding. Transition risks could pose a risk to macroeconomic and macro-financial stability if the transition is not managed in an orderly manner, with a planned reallocation of capital away from polluting activities towards greener alternatives.

The Reserve Bank of India (RBI) is therefore asking banks, non-bank financial corporations (NBFCs) like the Power Finance Corporation (PFC) and other regulated entities – which we collectively call financial institutions (FIs) – to consider transition risks arising from their lending activities (RBI, 2024). Central banks across the world's largest economies – Brazil, China, the EU, Mexico, the UK and the US – consider climate change a major financial risk. Many of these central banks have come together to share ideas and learnings under the auspices of the Network (of financial supervisors and regulators) for Greening the Financial System (NGFS).

Managing climate transition risks and taking advantage of opportunities in the net zero economy means creating the awareness and capability within financial institutions to consider the long-term consequences of their credit decisions. This is a journey and will take time to inculcate through financial entity workforces.

1.2 Purpose

This report aims to support the RBI and Indian financial institutions to identify and manage prospective risks associated with the low-carbon transition. Financial institutions have stated that they lack data and suitable methodologies and need more guidance to evaluate their transition risk exposures. It is true there are gaps and ambiguities in data, and methodological challenges. But it is also true that the Indian energy sector has extensive publicly available data, open-access energy models and projections produced by government and independent researchers that can inform decision-making, with sufficient guidance and capacity-strengthening.

This report illustrates the types of analysis that can be performed in India using publicly available data, NGFS scenarios and existing models. We aim to assess transition risks from lending to thermal power plants and the associated supply chains. The objective is to identify and help fill the evidence gaps facing financial institutions and their regulators. Financial institutions can draw on our data and methods with their own risk models and confidential loan portfolio data to evaluate exposure and the default risk. Our focus is on lending to thermal power generation because it is likely that this will be the largest near-term source of transition risk in the Indian economy, given

3 The other aspect of 'climate risk' is physical risks, which refer to the operational, credit or other risks to the financial sector owing to the effects of chronic changes, like rising temperatures or sea levels, and acute climate impacts like the increased severity and frequency of natural disasters. In general, if the goals of net zero are not achieved worldwide in the coming decades, the physical impacts of climate change will be substantial – even catastrophic. It is therefore important to achieve a rapid transition, even if this brings higher transition risks, as these can be partly mitigated with steady and consistent policy changes and good risk management.

its financial importance – electricity production accounted for 5.2% of outstanding credit in 2021 (Colenbrander et al., 2023) – and the likely speed of transition to non-fossil fuels, bearing in mind the favourable economics of solar.

Our efforts show what is already possible with publicly available data and models, but also identify shortcomings in the data, models or underpinning theory so that these may be addressed sooner rather than later. To further enrich the analysis, we interviewed experts to introduce details about how fossil fuel assets are financed in India, and how the contracts to compensate these long-term assets are structured, to better capture where in the supply chain credit risks sit.

Box 1 Research questions

1. **Can the NGFS scenarios be used** for projecting transition risks to the electricity sector, and how can they be **combined with local data**?
2. Focusing on the electricity sector and its supply chain, how will transition scenarios affect **coal-fired power's utilisation and stranding risk** and impact on supply chains?
3. What are the **implications for financial institutions** (separating out banks and NBFCs) that lend to the power sector?
4. Given the risks, how can the transition be **managed justly**?
5. What support should **RBI provide to help financial institutions strategically manage transition risks**?

Our analysis includes a review of Indian energy reports, data and models, and interviews with experts, government officials and RBI staff. The modelling uses data from the NGFS, a coal database and the PIER (Perspectives in Indian Energy based on Rumi) model.

The report is structured as follows:

Section 2 discusses the Indian policy context, existing work on transition risk by the RBI and some recent reports on transition risks by Indian researchers. Section 3 reviews the most recent NGFS transition scenarios and evaluates their applicability for India. We interviewed energy experts in India, asking whether the simplifying assumptions used by NGFS analysts can be improved upon to better reflect Indian circumstances. Section 4, the methodology, sets out how we have integrated data and models from different sources.

Section 5 presents results, setting out our projections of coal-fired power to 2047 for three scenarios. Section 6 looks at impacts, evaluating how the transition scenarios will manifest on the balance sheets of FIs. It also discusses contracts between power stations and other actors in the supply chain to assess who is exposed as coal power generation falls. Section 7 discusses the social aspects of the transition out of coal and how these have been tackled in other countries to ameliorate unjust transition.

Section 8 draws out some lessons learnt and suggestions for FIs, the PFC and the RBI to consider.

2 The Indian context

2.1 Policy and financial context

In India, policy on climate change is the responsibility of the Ministry of Environment, Forest and Climate Change. Overall policy towards electricity generation is the responsibility of the Ministry of Power, though the Ministry of Coal and the Ministry of New and Renewable Energy also have responsibilities to sponsor the interests of coal and solar photovoltaic (PV) and wind power, respectively. Under the Ministry of Power, the Central Electricity Authority (CEA) is responsible for short- and medium-term planning of investments. The most recent of these project electricity demand and supply through to 2032. Corporations under the Ministry include POWERGRID (operating its high-voltage transmission), the PFC (raising debt finance and lending to the power sector, and the value chain) and the NTPC (which owns around a quarter of India's installed capacity). This list is not exhaustive.

Many of these organisations produce their own projections and forecasts for internal planning, but these have often been inconsistent. Niti Ayog has been tasked with strengthening coordination between ministries and their bodies.[4] It has developed an open-access online and a downloadable spreadsheet tool to undertake energy scenarios till 2047 – IIESS47 (Indian Energy Security Scenarios to 2047, described later) – and an India energy modelling forum.

States are responsible, with the Union government, for electricity. State electricity regulatory commissions oversee and plan transmission, distribution and retail. The state electricity boards/DISCOMs (state-owned electricity distribution companies) supply power to customers, operate the distribution grid, set tariffs and own around a quarter of generation capacity. The balance is purchased power from private and central government-owned generators.

There are some issues worth discussing in more detail.

Cost recovery. It is common for commercial and industrial customers to cross-subsidise household tariffs. The PFC lends to states and provides consultancy advice to help them manage their financial solvency. In 2022–2023, DISCOMs sold ₹2.5 lakh crore of power but paid ₹2.7 lakh crore (PFC, 2024b). This represents an improved level of losses compared with recent years. The ongoing distressed state of DISCOMs inhibits investment in the transmission and distribution needed for the expansion of renewable electricity. The government launched a bailout of the DISCOMs in 2021 (the fifth), budgeted at ₹3 lakh crore (Ministry of Power, 2021).

Two-part tariff system. Our discussions with experts highlighted that many generators are shielded from low plant load factors (PLF) by their two-part tariff contracts with the DISCOMs.

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4 www.niti.gov.in/verticals/energy

India has experimented with different tariff structures over time (CERC, nd). Prior to 1992, the lack of generation capacity meant thermal power plant received a single-part tariff from DISCOMs, as generators operated as baseload. In 1992, following the KP Rao Committee report, two-part tariffs were introduced, so DISCOMs paid generators for fixed and operating costs separately – with the fixed cost payments to be made regardless of whether the power plant was scheduled. In 2004, generators and DISCOMs started to use the Availability-Based Tariff (ABT), whereby a generator could recover the fixed charge only if the power plant was maintained in a fit condition, evidenced by achieving minimum levels of scheduled PLF. There was a huge increase in investment in new coal plants under the ABT system, with some 150 GW of coal starting operations after 2005, far exceeding the total under earlier systems. The net result is that some plants are paid even when they are inactive.

The two-part tariffs incentivise DISCOMs to procure electricity generated from coal plants since the fixed cost must be paid regardless of demand. It also relieves coal generators from the cost of transition since the fixed cost is transferred from the generator to the DISCOM. Investors in coal plants are consequently shielded from the market effects of increasingly cheap renewable generation.

Increased intermittency in the system. Solar PV and wind will be cheap and plentiful in daytime or when the wind is blowing, reducing the usage of higher marginal cost thermal plants. Peaker plants like coal will have to operate flexibly and ramp up to meet demand. Our analysis assumes battery storage usage will rise, and indeed costs of 'solar + battery' generation is dropping rapidly (Energy Storage News, July 2024). There remains a role for technologies like coal that can generate electricity reliably, especially if battery capacity cannot keep pace with renewable capacity, but the role will be different from today's: rather than providing baseload power, coal plants will need to be adapted to quickly ramp up and down at moments of peak demand (Bolton et al., 2020).

Plant load factors. In *2022-23* coal-fired power plants in India had an average PLF of 56.6% (Ministry of Power, nd). That means much of the time the plants are idle. Experts noted that the expected PLF in CEA reports has been continually scaled back. State governments and utilities are reconciled to further drops in PLF and the need for periodic bailouts of DISCOMs as a result of their two-part tariff payment obligations (described above).

Regional distribution of generation capacity. India's grid infrastructure improvements over the past 10 years mean that it is fairly well integrated, so regional variations in electricity supply and demand can be balanced without much complication – at least given the current state of electricity demand. Future demand will require substantial additions to the grid. One interviewee commented on the investment needed for the evacuation of renewable power from remote regions like Ladakh to population centres.

Future demand changes *will place* new stresses on the system. Delhi, for example, is evaluating the accommodation of large-scale electric transport charging across the city and throughout the day. Some experts noted that DISCOMs lacked both technological and human capacity to handle these changes and represented a bottleneck to advancement, especially those DISCOMs making structural losses.

Ability for India to deploy renewables quickly enough. There is significant uncertainty about whether solar PV and wind can be deployed fast enough to meet growing demand. Past rates should not be seen as indicative of future rates as transition can grow quickly. New generation capacity to meet projected demand in the net zero scenario is enormous, and may seem infeasible given current construction rates. However, it tallies with IEA's most recent estimates of year-on-year growth and expectations for the coming decade as the price of solar continues to fall (IEA, 2024). China installed 600 GW of solar between 2017 and 2023 and is projected to add 2,000 GW between 2023 and 2028. According to the Chinese National Energy Agency, it added 216 GW of solar PV capacity last year (Reuters, 2024), confirming a precedent for such immense growth rates – indeed, China met its 2030 target of 1,200 GW of wind and solar in July of 2024 (Bloomberg, 2024). If India is to replicate this feat, it will require a massive drive to indigenise low-cost, reliable solar equipment production – and, according to India's union minister for new and renewable energy, ₹30 lakh crore ($357bn) to achieve its own 2030 target of 500 GW of renewables (Times of India, 2024).

2.2 RBI work on transition

The RBI has signalled through policy papers, staff papers and speeches by senior staff that Indian financial institutions need to incorporate climate risks into their decision-making. These signals have culminated in the Draft Disclosure Framework on Climate-related Financial Risks published in 2024 (RBI, 2024). This will be applied to all the financial institutions supervised by the RBI, including Indian banks, NBFCs and all-India financial institutions (like the National Bank for Agriculture and Rural Development, NABARD). The Framework has four pillars covering governance, strategy, risk management, and metrics and targets, which are being phased in progressively. The risk management disclosures should be fully implemented by larger financial institutions by 2028; quantified targets are requested a year later.

The Draft Disclosure Framework builds on the 'Discussion Paper on Climate Risk and Sustainable Finance' (RBI, 2022). This paper set out the RBI's initial thinking of climate-related disclosures and invited financial institutions to comment. It drew heavily on the principles laid out by the Taskforce on Climate-related Financial Disclosures (TCFD) in 2017, which first suggested the use of scenario analysis for understanding climate risks, as well as the four pillars for disclosure.

In this context, it is worth noting that recent work to gauge bank readiness to deal with climate risks has found that the majority are highly unprepared. Most do not even disclose scope 1 and 2 emissions, and none have completed forward-looking assessments of climate risks (Asapur and

Fernandes, 2022). Two banks, according to closed consultations around this paper, have started to incorporate the use of NGFS scenarios in their risk management but have found it challenging to connect them to financial impacts.

As well as issuing this draft regulation, staff from RBI have undertaken three analyses of transition risks in the Indian economy.

- RBI undertook a pilot stress test with 15 domestic and foreign banks operating in India on their exposure losses from lending to electricity generation, transport and energy-intensive manufacturing. Banks identified substantial increases in the credit loss potential of up to 146% by 2050 from fossil fuel price rises (Sinha and Bhanvadia, 2024).
- RBI conducted an unusual transition risk analysis looking at returns from NIFTY Energy Index and Coal India Limited compared to benchmark indices for the whole market. The assumption is that businesses with substantial stranded assets will underperform compared to the market. A synthetic climate stress was calculated from the parameters derived from this analysis (RBI, 2023).
- RBI assessed India's iron and steel transition costs (RBI, 2021). Reducing carbon dioxide (CO_2) emissions by 33-35% between 2005 and 2030 incurred a capital cost of ₹3,700 crore borne by customers and shareholders.

2.3 Recent analysis by independent researchers

Many independent researchers have reviewed the future of the Indian energy sector and the implications for the country's financial sector. A number of relevant papers on transition risks from the power sector were published in a volume on the role of coal in India's energy mix (Mohanty and Sarkar, 2024).

A good recent overview of India's energy trilemma (Basu and Nayak, 2024) examines the policy challenge of balancing access to electricity, security of supply and sustainability of power generation. For two decades, expansion of the electricity sector has been the government's policy priority, to ensure security and support economic growth and the consequential increase in electricity demand. This expansion has resulted in India now having the world's second largest fleet of coal-fired power stations after China, and a young one. Renewables, in recent years solar, are encouraged through mechanisms like capital subsidies and renewable purchase obligations, so India can exploit its abundant solar resources and falling technological prices. The need for upfront investment highlighted above conflicts with the desire to keep prices low. Low household electricity prices are maintained through subsidies to the state electricity boards. However, delays in disbursing the subsidies requires the DISCOMs to borrow unsustainability, resulting in high borrowing costs and repeated bailouts. Simultaneously, electricity transmission and distribution are being extended to ensure every village has access to power. Basu and Nayak discuss the socioeconomic challenges from the trilemma and warn that concern for employment linked to coal power and its supply chain has resulted in entrenched support for coal in some northern states.

We discuss the scale of the 'Just Transition from Coal' challenge and how policy can mitigate social concerns being a barrier to phasing-out coal in Section 7.

On the issue of projecting demand, doubt has been cast on the quality of strategic planning by the electricity sector, with forecasts consistently overestimating demand growth (Dahiya et al., 2024). Peak electricity demand was 216 GW in April 2022, compared with CEA's forecast of 239 GW made in 2019's long-term electricity projection forecast (in the 19th Electric Power Survey, EPS19). EPS18, conducted in 2010–2011, forecast demand in 2022–2023 to be 50% higher than outturns.

One article observes the institutional challenges in aligning incentives to avoid unnecessary investment in surplus capacity. Fossil fuel generators are insulated from the consequential fall in demand for their high-cost power by the design of their tariff structures with the DISCOMs (see above). Renewable generators are themselves somewhat shielded by being given a 'must-run status', always being scheduled for despatch by the grid operator (Mandal, 2024).

The Centre for Social and Economic Progress (CSEP) in 2019 developed nine scenarios for electricity generation requirements till 2030, considering slowing growth in demand for power outpaced by the earlier expansion of coal generation, resulting in a deteriorating PLF. The study recommended phased deployment of planned new plants and accelerated retirements for less efficient ones (Tongia and Sahil, 2019).

The Council on Energy, Environment and Water (CEEW) in 2021 published a study comparing the thermal efficiency and costs of India's fleet of 198 GW coal-fired power plant and recommended the sequencing of the closure of the oldest and least cost-effective quarter to relieve financial pressure from lenders and operators (Ganesan and Narayanaswamy, 2021).

There have been fewer articles on the scale of transition risk. Climate Bonds Initiative and ODI have published work on transition risks across energy-intensive sectors of the Indian economy (Vaze et al., 2023), using debt finance to assess financial sector exposure. Their findings reveal India's financial sector is much more heavily exposed to low-carbon transition risks than standard borrowing classifications might suggest. For example, three-fifths of lending to the 'mining' sector is for oil and gas extraction, while one-fifth of 'manufacturing' debt is for petroleum refining and related industries. They also found that only 17.5% of lending to the power generation sector was to pureplay renewables. Most of this debt was five to 10 years in tenor.

3 NGFS scenarios for transition risks to India's electricity sector

3.1 Overview of the NGFS scenario work

The RBI, like all central banks, is mandated to ensure that financial institutions maintain adequate reserves to remain solvent and liquid under plausible financial shocks (micro-prudential regulation), and the financial system as a whole can withstand economic shocks (macro-prudential stability). Since the 2008 global financial crisis, central banks have asked financial institution to simulate economic and financial shocks on their loan portfolios – so-called 'stress tests'.

NGFS has laid out a set of scenarios to help estimate potential climate risks over the long term, with guidance on how to conduct climate stress tests (NGFS, 2023). The guidance seeks to support central bankers to assess whether current lending practices are exposing financial institutions to excessive risks from greenhouse emission mitigation measures (i.e. transition risks) and physical damage to economic assets (i.e. physical risks).

As the first global effort of its kind, the NGFS tool has many advantages over other methods of estimating climate risk. The models that create the projections often either are more sophisticated than local versions or project their scenarios to longer time horizons, which is a key feature to understand the full delayed effects of climate change. The standardised scenarios and assumptions underpinning them enable high-level comparisons between those who use them, both internationally and domestically, and consultation for this report suggests that two banks have explored the use of NGFS scenarios for transition risk assessment in India already.

On the other hand, the global assumptions of the NGFS scenarios and models necessarily lack the level of detail that can be achieved using models with narrower scope. This is especially true for modelling subnational climate risks and impact. Some of the scenarios may also cause confusion when used at a national level: for example, the NGFS Net Zero (NZ) scenario imagines the global achievement of net zero by 2050, while India's net zero target is for 2070.

This section explores some of these NGFS projections and their plausibility as reflections of future paths for India, to evaluate their potential use by Indian financial institutions in their risk modelling. To support the analysis, the authors conducted four interviews with Indian experts to gauge the extent to which they considered the NGFS projections to be plausible for India. These informal and anonymous interviews were structured around a questionnaire (see Appendix A).

The projections were built with NGFS' scenario explorer, using the Global Change Assessment Model (GCAM) integrated assessment model – the choice of which is detailed in Appendix B. The section covers only three of the seven available NGFS scenarios, following consultation with RBI:

- **Nationally Determined Contributions (NDCs).** This global scenario reflects the extrapolation of global pledges as made in NDCs in 2021, resulting in only limited CO_2 reduction, global warming of 2.6ºC by 2050 and therefore high physical risks and lower transition risks. For India, this implies a CO_2 peak in 2060, and emissions higher in 2100 than in 2025. This is not as pessimistic as the NGFS 'current policies' scenario. The scenario will likely change with the next round of updates to NDCs, in 2025.
- **Net Zero 2050 (NZ).** This global scenario keeps warming below 1.5ºC by assuming that ambitious policies are implemented immediately worldwide, leading to rapid transition. This therefore implies low physical risks and moderate to high transition risks. It assumes differentiated responsibility, with India's CO_2 emissions projected to reach net zero by 2060, balanced by advanced economies reaching net zero earlier and also implementing carbon sequestration at scale. This scenario implies a faster transition for India than its stated net zero by 2070 ambition and reflects the possibilities that targets may be updated, or technology opportunities may accelerate and costs fall faster than currently forecast.
- **Delayed Transition (DT).** This assumes that annual emissions keep rising until 2030, at which point rapid and strong policies are enacted to keep warming below 2ºC. It assumes low availability of CO_2 removal technologies and therefore entails a higher carbon price than NZ (the carbon price is assumed in the models to stand in for a range of policies). Physical risks are high, although less than in the NDC scenario, and transition risks are also high. This scenario sees India nearing net zero CO_2 emissions in 2070, ahead of the current schedule but with a later start than that required to meet the NGFS NZ scenario.

These scenarios are compared against two further projections of energy demand and generation, created by branches of India's government, to gauge their plausibility. These are:

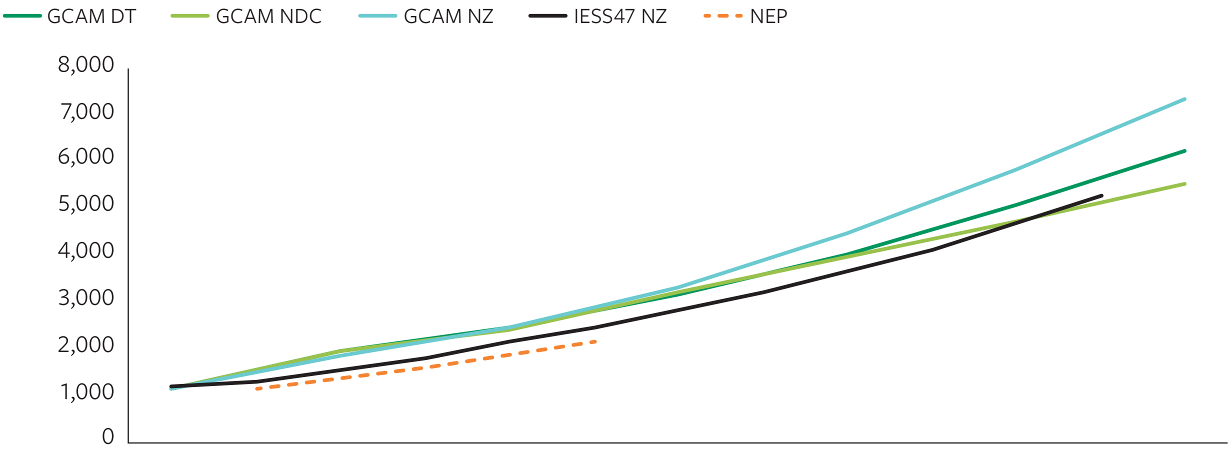
- **India Energy Security Scenarios 2047 Net Zero (IESS47 NZ).** This is the most established of the IESS47 scenarios, and reflects India's achievement of developed country status by 2047 and net zero by 2070. See Appendix B for more details. The demand trajectory is close to the NGFS NZ (by 2050) trajectory. Projections are available till the year 2047, and the NGFS scenarios are therefore shown until 2050 for comparison.
- **National Electricity Plan (NEP).** Modelled by CEA (2023b), this estimates electricity demand and generation between 2022 and 2032. This is likely to be the most accurate projection representing existing government policies in 2022, although – as described in Section 2 –CEA's projections have consistently overestimated Indian electricity demand growth over the past decades. Its main limitation is its short time horizon, extending only eight years from the publication of this report.

It is important to note that, although the focus of this paper is on transition risks as they are highlighted in the chosen scenarios, the consequences of slower and less financially risky transitions – i.e. less ambitious climate action – will likely result in very high physical risks, with all the effects on the financial sector and broader society that those entail. A rapid but orderly and just transition away from fossil fuels towards low-carbon power generation and greater energy efficiency is overall a much cheaper and less risky proposition than a climate-changed world.

3.2 Comparing estimates of India's electricity demand and generation to the middle of the century

All models and scenarios show substantial growth of electricity demand and generation over the periods they describe (Figures 1 and 3), reflecting India's rapid economic and population growth trajectory over the coming decades. The GCAM NZ scenario forecasts the highest levels of electricity demand and consumption, mainly as a result of the fastest and highest extent of electrification across all sectors. IESS47 NZ (starting from slightly higher demand in 2020) grows more slowly over the next decade but by 2045 it has overtaken GCAM's NDC scenario to forecast an electricity demand increase of 5254 TWh by 2047. Meanwhile, the NEP tracks a similar trajectory until it ends in 2032 but is less ambitious about the increase in demand.

Figure 1 GCAM model electricity demand projections for India (TWh)



	2020	2022	2025	2027	2030	2032	2035	2037	2040	2042	2045	2047	2050
GCAM DT	1161.4		1940.3		2435.1		3141.3		4034.0		5062.3		6258.5
GCAM NDC	1162.3		1920.2		2407.6		3191.7		3960.3		4709.6		5513.5
GCAM NZ	1162.3		1859.9		2428.7		3312.9		4461.9		5842.7		7365.2
IESS47 NZ	1200.8	1274.3		1799.5	2170.2	2437.8		3197.3		4131.9		5254.4	
NEP		1138.4		1610.1		2133.4							

Source: authors' calculations based on data from NGFS

Most of the experts interviewed considered these long-term demand growth rates (Table 1) to be plausible, considering the different levels of electrification assumed in each scenario. The growth rates over the first 10 years, on the other hand, provoked different reactions. Some experts were optimistic about even the levels forecast in the NGFS GCAM models: given that India's per capita electricity demand is among the lowest in the world, there is scope for both broadening and deepening electricity penetration. Moreover, electrification in the more ambitious scenarios, increased cooling needs as temperatures rise and continued gross domestic product (GDP) growth all combine to support their optimism. On the other hand, others noted that, in the past, CEA's projections have consistently overestimated demand. One respondent was even more conservative, suggesting that a maximum of 4.5–5% annual growth in electricity demand was more realistic because the income elasticity would fall as the sector composition of growth became less energy-intensive. As explained in Section 4, this feedback contributed to the more conservative choice of IESS47 NZ – the black line in Figure 1 – as the demand projection to be used as the baseline for the authors' analysis in the rest of this paper.

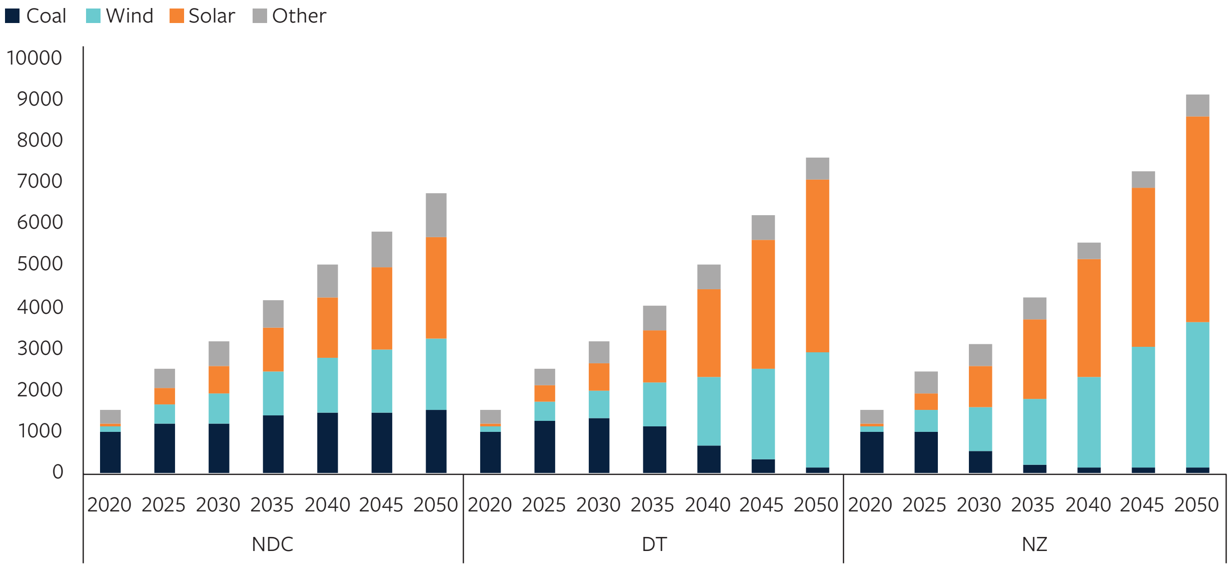
Table 1 Electricity demand growth rates by scenario

Scenario	Annual demand growth rate over first 10 years	Annual demand growth rate over 25 years
GCAM NDC	7.6% (2020–2030)	5.8% (2020–2045)
GCAM NZ	7.7% (2020–2030)	6.7% (2020–2045)
GCAM DT	7.7% (2020–2030)	6.1% (2020–2045)
IESS47 NZ	6.1% (2020–2030)	5.8% (2022–2047)
NEP	6.5% (2022–2032)	N/A

Source: authors' calculations based on data from NGFS

NGFS projections for electricity generation (Figure 2) match those for electricity demand: all anticipate massive growth, the NZ scenario most of all. The main difference between them is in the energy mix: despite the rapid growth of total generation under the NZ scenario, coal generation is rapidly phased down in the late 2020s and early 2030s. The DT scenario also sees a phase-down of coal, after a peak in 2030, albeit not so rapidly, while the NDC scenario sees coal generation rising throughout the period – although its share of the energy mix does drop dramatically.

Figure 2 GCAM Electricity Generation Projections (TWh)



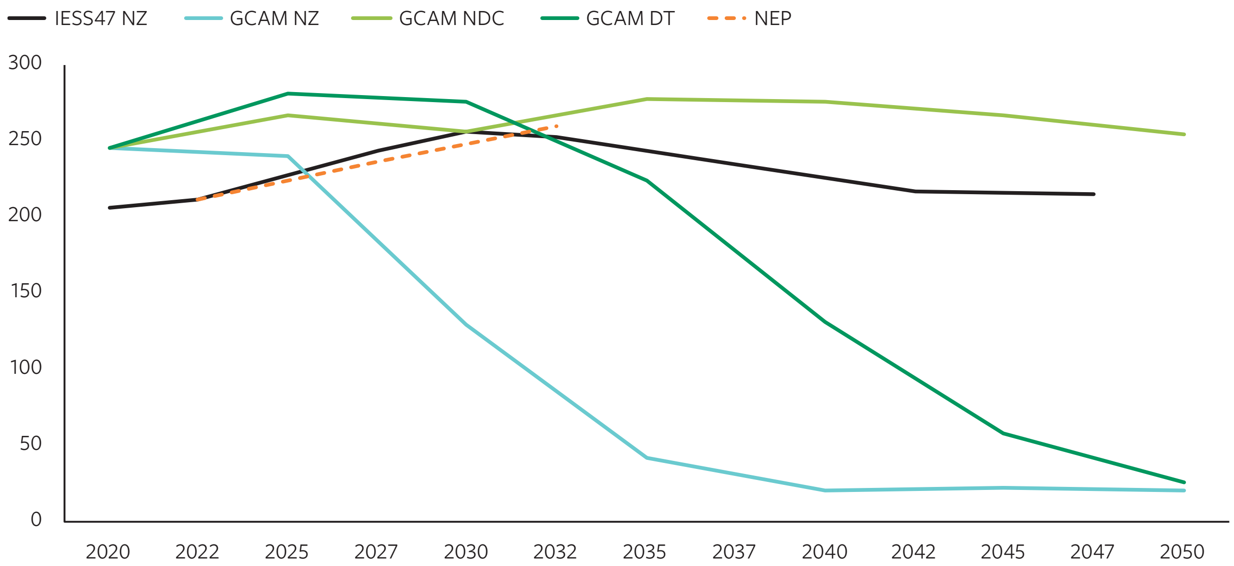
Source: authors' calculations based on data from NGFS

These differences in the energy mix imply huge increases in installed wind and solar capacity, and a corresponding assumption of increased storage capacity. However, in the NGFS NZ scenario, this is accompanied by a rapid decline in coal generation from 2025 (Figure 3), while at the same time the greatest demand for electricity is projected. The DT scenario implies a slight increase in coal generation in the 2020s, and then follows a similar trajectory to the NZ scenario from 2030. Meanwhile, coal remains important throughout the NDC scenario: a slow increase in total coal generation to 2040 that stagnates during the last decade means that, although coal's relative share of the electricity supply drops rapidly, the coal plants are still in use by 2050.

However, most experts interviewed considered GCAM's capacity projections for renewables across all scenarios to be too high. It is true that variable renewable capacity will have to significantly overcompensate for other forms of generation, because the utilisation factor of variable renewables is lower, and therefore an increase in electricity generation capacity, approaching the extents projected by the GCAM capacity scenarios, would be necessary to support massive supply increases based on renewables. But most experts agreed that India has been struggling to meet its existing renewables capacity targets, which imply 50 GW of new build every year until 2030. Given limited construction so far, it seems optimistic to assume that the country can manage the much higher construction levels required in the short term by the GCAM scenarios.

All experts were sceptical of the implied decline in coal capacity in the NZ and DT scenarios, seen in Figure 3. Even if coal generation declines at the suggested rates, the more likely outcome would be lower PLFs for existing coal plants, rather than the permanent decommissioning of the plants. First, there are political considerations at stake: coal is of national security importance, since India has its own coal resources, and it is more reliable than variable renewable technology in the absence of improved electricity storage technology. Second, even in a system dominated by renewables, there is still a requirement for reliable backup generation (often confused with baseload generation) to quickly ramp up and down to reflect the variability of renewables. In other words, the expectation is that coal plants will be kept on the books for the foreseeable future, even if they become inactive. The implication of this ramping requirement is that at least some coal plants will be needed until alternative technology matures, but not all agreed on which coal plants would be more suitable: whether new, more efficient coal plants using supercritical technology should be built to replace older models or whether it is more efficient to just keep the older models online at a reduced PLF.

Figure 3 Coal capacity projections from GCAM, IESS and NEP (GW)



Source: authors' calculations based on data from NGFS

Alongside the ambitious estimates of electricity demand and especially of electricity generation capacity, the NGFS has some considerable limitations that should be accounted for while analysing transition risks in India.

The first of these is that the generation capacity projection method of the GCAM model assumes away stranded assets. GCAM does not models countries' fleet of power plants, and does not capture individual plants' capacity, leverage or vintage. Instead, it derives capacity from its generation projections using a regional levelised cost adder for each technology (JGCRI, 2022) – i.e. it formulaically calculates the level of capacity for a given amount of generation. As we demonstrate in our earlier paper (Vaze et al., 2021), India has a young fleet of coal plants of an average age of 15 years. The levelised electricity cost of coal power is based on an ageless, divisible power plant abstracted away from the actual Indian vintage of the power station. This means GCAM does not provide insight into capital stocks stranded by transition risks, including the rapid capacity expansion of cheaper forms of electricity generation. Likely as a result of this method, its data for 2020 starts much higher than in the Indian models: the three GCAM scenarios record

245 GW of capacity in 2020, compared to the 205 GW in IESS47 and 2010 GW in 2022 recorded in both IESS and NEP. GCAM capacity projections were therefore not used in this paper's further analysis.

Another key limitation of the NGFS models is the low resolution of energy balancing. The NGFS scenarios balance supply and demand every year, whereas in reality the system operator must match demand and supply across local grids every hour. The mix of generation technologies changes over the day and between seasons. A more granular energy model than the NGFS models is needed to account for these different needs and to provide a more accurate forecast of electricity demand and generation.

Based on these limitations and the overly ambitious projections of all three GCAM scenarios, **the authors do not recommend the use of NGFS scenarios alone by financial institutions to assess transition risks**. The rest of this paper uses NGFS outputs only as a skeleton for analysis, and supplements these with more detailed, India-specific models and data to flesh out regional, intra-year demand/supply, and vintage of power generation assets. The methodology for this analysis is detailed in the following section.

4 Methodology: quantifying transition risks to India's thermal power

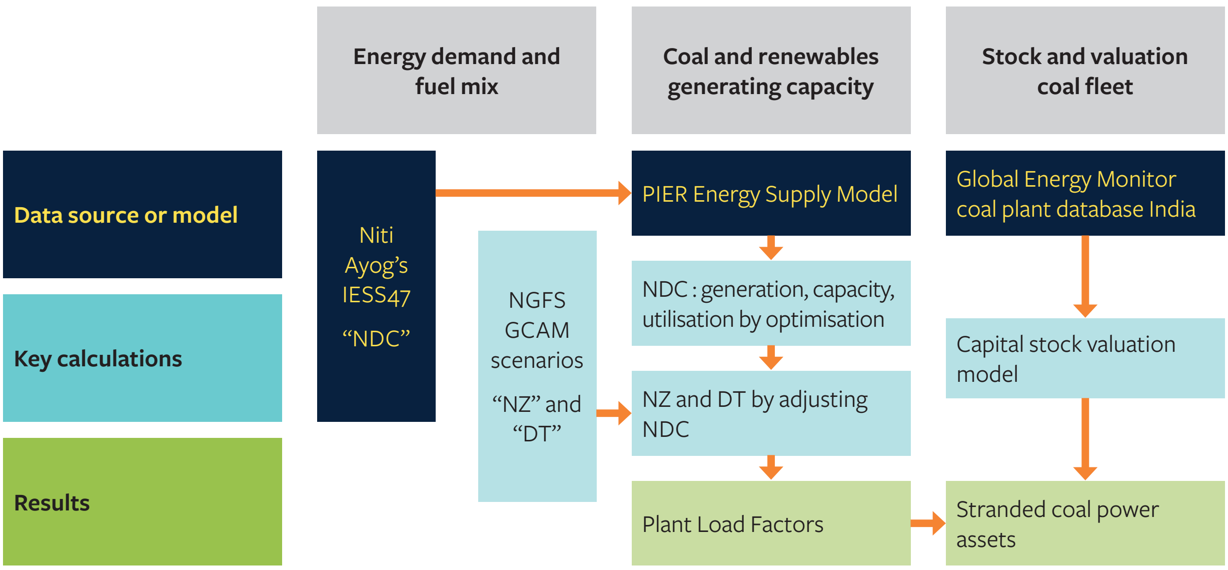
Several datasets and models were integrated to build a picture of the transition risk from stranded coal assets. Our goal was to calculate the utilisation of coal-fired power stations assets and hence any changes in PLF. We believe that financial institutions seeking to understand their exposure from lending to coal-fired power will need to undertake similar analysis.

Figure 4 presents a simplified depiction of the different data sources and models. The blue boxes are data or models that input into our analysis, grey boxes were significant calculations we undertook, and green boxes are the key results feeding into the next stage of the calculation. Reading from left to right there are three stages:

1. projecting electricity demand and relative contribution of coal and renewables in generation for scenarios NDC, NZ and DT using data from IESS and NGFS GCAM scenarios
2. using PIER to model the amount of solar, wind and coal generation, storage and interregional electricity sales to ensure supply and demand always balance and
3. building a plant-level model of the value of coal-fired power plants to track their depreciation, new build and utilisation and hence the total fixed costs being 'stranded' every year.

We do not attempt to calculate the exposure of individual banks or default risks since the data needed are not publicly available. Financial institutions will need to use their existing internal risk models and loan data to make these assessments.

Figure 4 Models and data that fed into the analysis



Source: Authors

4.1 Setting electricity demand for the three scenarios

The NDC electricity demand scenario was assumed to follow the IESS47 NZ (by 2070) trajectory, which has a similar trajectory and stated policy goal to the NGFS NDC scenario. IESS47 also happens to be quite similar to the NGFS NDC scenario (see Figure 1).

The NZ and DT electricity demands were based on scaling the above NDC demand by the ratios of NDC:NZ and NDC:DT from the NGFS GCAM results. Overall demand for power is higher than in the NDC scenario, to reflect electrification of transport and industry. These two derived demands are similar but a little lower than the NGFS demands with the same name.

We used this approach to anchor our results to India's internal modelling work in support of its NDC determination.

4.2 Modelling energy technology (generation and storage) new capacity using the PIER Energy Model

As we describe earlier, the NGFS models do not model the stock of coal-fired power stations so cannot provide insights into issues like stranded assets or changes in PLF. Fortunately, India has several energy and electricity models, developed by the central government and independent researchers. These provide more granular detail at regional or state level and can better capture local circumstances than can the integrated assessment models used by NGFS. There are also a handful of models developed by intergovernmental organisations and foreign research institutes worth examining. Please see Appendix B for the options and our assessment of each against our needs.

Ultimately, we decided to use the Prayas model, *Perspectives on Indian Energy using Rumi* (PIER). PIER already includes Indian data on electricity technologies, regions, pre-existing capacity of electricity generation and sunlight and wind characteristics.

PIER models generation, storage and interregional transfer of electricity for each region and time-slice (time of day and season). It is configured to run till 2032. We used it to model new generation needed to meet the annual electricity demand only in the NDC scenario.

To run PIER, we extended the assumptions to 2047. The model includes the maximum rates at which renewable technologies and batteries can be rolled out in different states. We tripled the maximum rate for wind to 42 GW a year and solar PV to 70 GW per year. By way of comparison, wind installation in 2023 was 2.8 GW and the NEP assumes installation of around 10 GW/year between 2027 and 2032. The constraint on solar and wind installation causes coal to re-emerge after 2032 to meet the continued growth in electricity demand.

We also reduced the annual cost reductions of wind and solar PV beyond 2030 assuming the assumed rate of cost reduction could not persist indefinitely. We calculated the new generation needed for the NZ and DT scenarios, which do not allow new coal capacity beyond 2024 (NZ) or 2030 (DT).

Because the NGFS produces results at national and annual level, there was insufficient granularity to rerun the optimisation for the other two scenarios. Instead, we adjusted the NGFS NDC results for the DT and NZ scenarios in these steps:

1. using the revised demand for electricity for each year for the two scenarios and allocating this to the five Indian regions, and the time-slices
2. using the share of electricity produced from coal, solar and wind in each scenario, rescaling the annual regional electricity demands from the NDC scenario
3. assuming that new wind and solar PV would be built to accommodate the projected growth in the DT and NZ scenarios without constraint.

Further details are available on request.

Box 2 Definition of regions used in PIER

- **NER (North-Eastern):** Assam (AS) and Northeast (NE) consisting of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura
- **ER (Eastern):** Bihar (BR), Jharkhand (JH), Odisha (OD), West Bengal (WB)
- **NR (Northern):** Delhi (DL), Haryana (HR), Himachal Pradesh (HP), Jammu and Kashmir (JK), Punjab (PB), Rajasthan (RJ), Uttarakhand (UK), Uttar Pradesh (UP)
- **SR (Southern):** Andhra Pradesh (AP), Karnataka (KA), Kerala (KL), Tamil Nadu (TN), Telangana (TS)
- **WR (Western):** Chhattisgarh (CG), Goa (GA), Gujarat (GJ), Madhya Pradesh (MP), Maharashtra (MH), Union Territories (UT)

4.3 Valuing the stock of coal-fired assets

We are interested in knowing the value of power plants that are stranded through the energy transition. Most energy models, including PIER, do not keep track of the value of the assets. To do this requires modelling the construction, depreciation and closure of each power plant. We used data from Global Coal Plant Tracker[5] cross-referenced with India's NEP (CEA, 2023b) to a stock valuation model of the Indian coal fleet developed by the authors. Details are given in Appendix E.

5 https://globalenergymonitor.org/projects/global-coal-plant-tracker/

5 Results for the electricity industry

5.1 India's electricity scenarios analysed using PIER

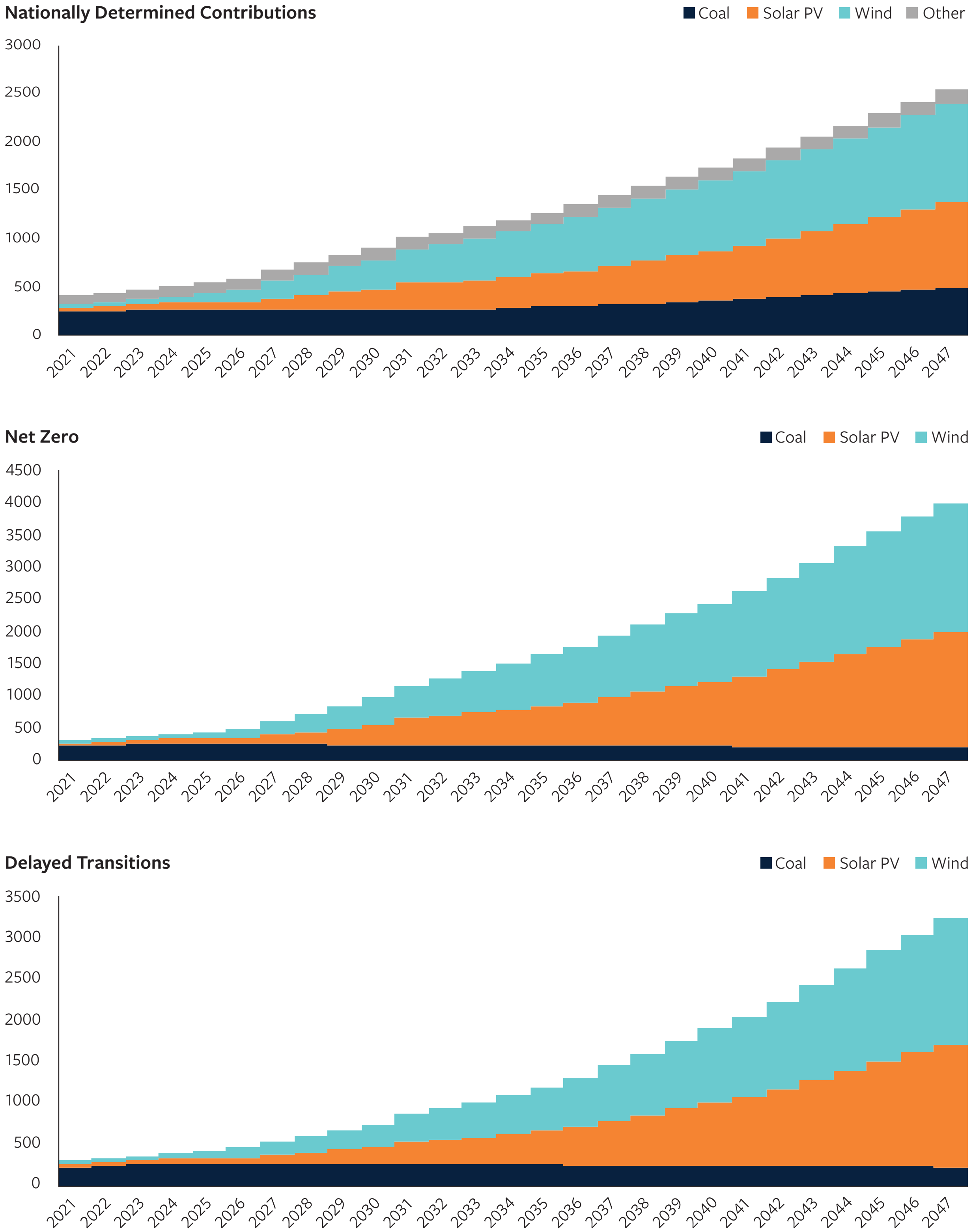
This section looks at the NDC scenario as projected under PIER, and the DT and NZ scenarios derived from the PIER output. PIER outputs can be viewed across regions, which is helpful for financial institutions that have regionally concentrated customer bases.

Under the NDC scenario, new solar and wind make up 75% of incremental generating capacity from 2024. Coal remains important, doubling in capacity between 2021 and 2047 to 498 GW.

Results for new capacity are presented in Figure 5. India's fast growth in electricity demand means far more installed capacity is needed in future years: the annual new capacity of wind and solar rises to 250 GW per year in 2046 for NZ. This was India's *total* installed capacity as recently as 2012. Total installed capacity reaches 4,000 GW in 2047 in the NZ scenario, around a third more than in the NDC scenario. Around 48.5 GW of capacity needs to be added annually this decade to match this surge in demand. This seems an incredibly high incremental growth rate, except for the fact that, in the first half of 2024, solar PV installations reached an all-time high of 14.9 GW (Mercom, 2024).

Figure 6 shows the regional dimension to the evolving share of renewables in total generation. Through population and economic growth, the Northern region is projected to see rapid growth in electricity demand; this growth will be largely met by renewables in every scenario. The Eastern region has more modest growth in demand and more installed capacity; it remains highly dependent on coal right through to 2047. The Southern region is already predominantly renewables by 2030, and more specifically wind. In the NZ scenario, the cessation of new coal after 2024 drives a substantial rise in wind and solar. To balance the grid, there will also need to be commensurate investment in storage.

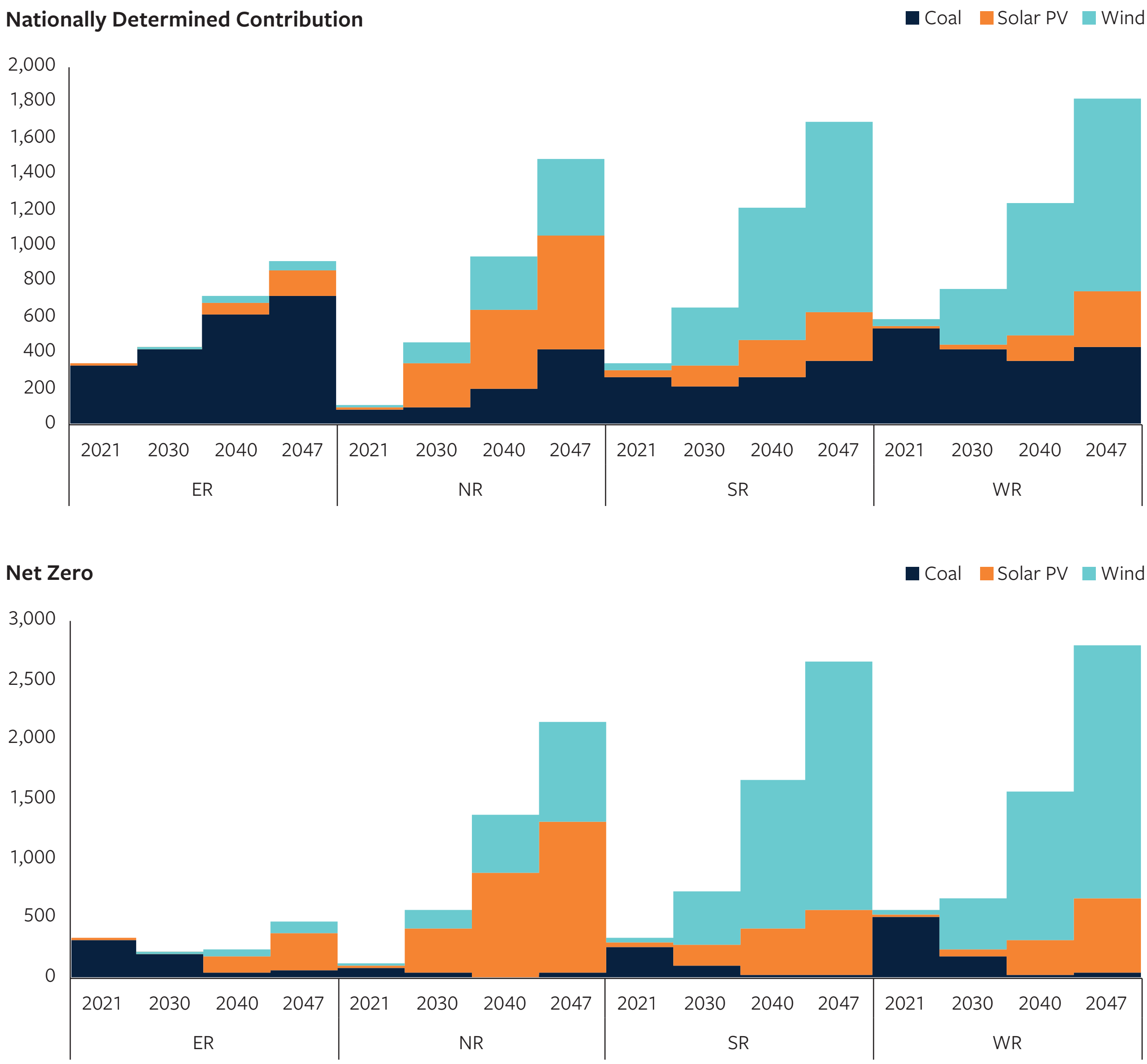
Figure 5 Installed generation capacity by generation technology: NDC, NZ and DT



Source: NDC scenario modelled using PIER model, NZ and DT derived by authors

Figure 6 indicates that different Indian states would have varied levels of exposure to transition risks based on the current proportion of thermal power stations in their territory and the age of those plants. Our coal fleet database shows the share of coal in each state's installed capacity varies from 0% (Delhi, Jammu and Kashmir) to 90% (West Bengal). Coal comprises more than 70% of the installed capacity in the east of the country, while the states in the south and west have heavily invested in renewables over the past decade (though coal remains the dominant source of electricity throughout the country).

Figure 6 Regional electricity generation from coal, solar and wind in selected years (GWh)

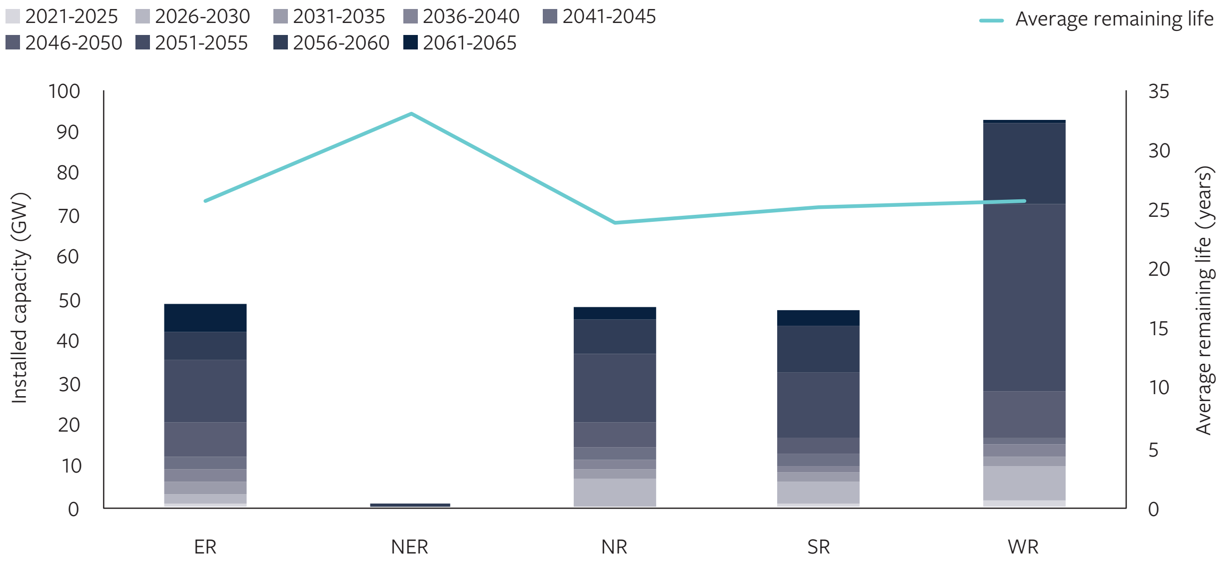


Source: NDC scenario modelled using PIER model, NZ derived by authors

5.2 Closure of Indian coal fleet

Figure 7 shows the scheduled closure dates of the Indian coal fleet. Because of the intensity of construction in the past decade, well over 50% of plants are not scheduled for decommissioning till after 2050. On average, Indian coal power plants are around 15 years old, so have around 25 years of production life remaining; there is little variation across the country.

Figure 7 Scheduled volume of closure of Indian coal plant (GW) by five-year bands and average remaining life



Source: Authors, calculated from data in Global Energy Monitor, 2024. Global Coal Plant Tracker 2024, checked against CEA

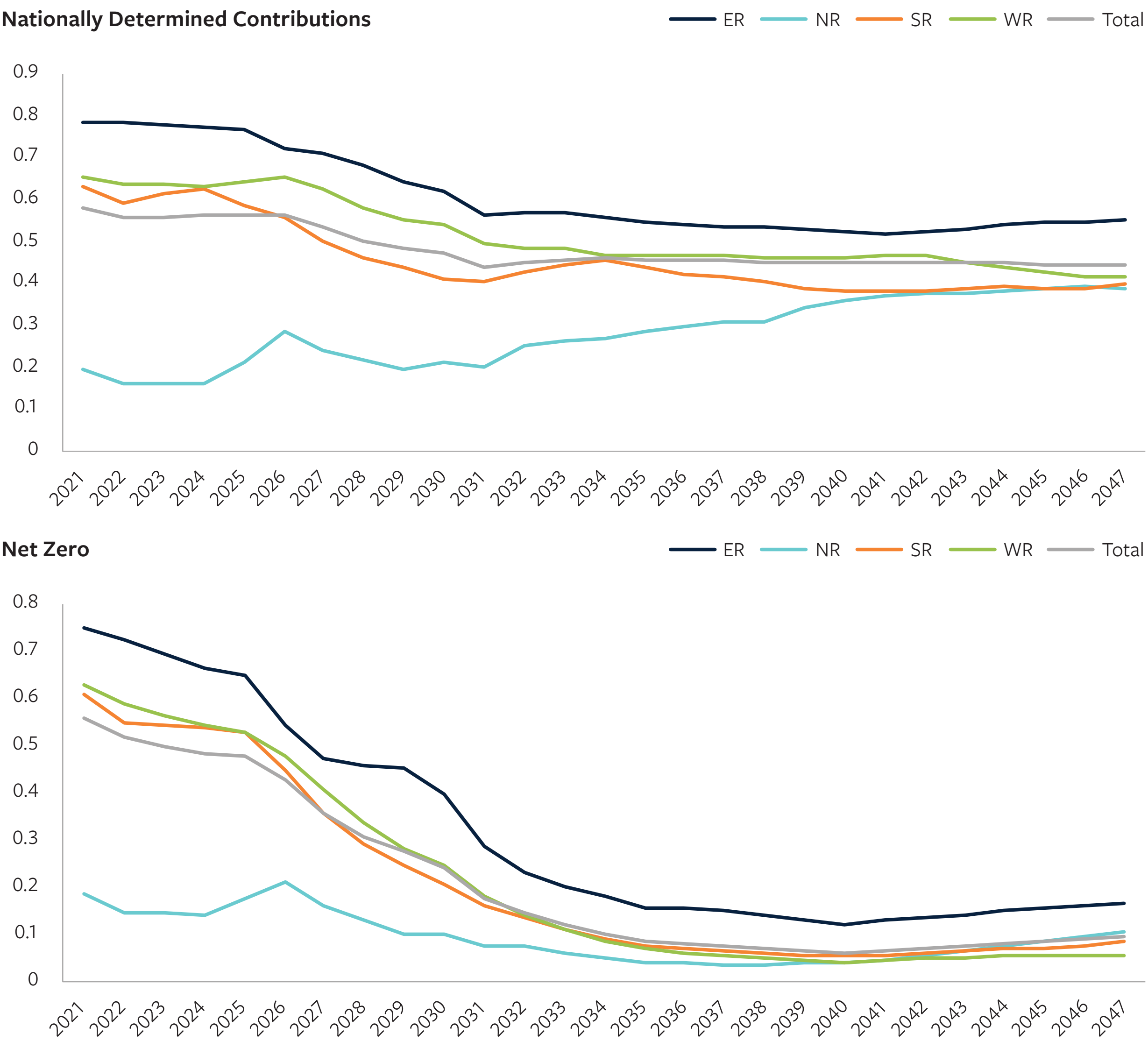
While the scheduled closure dates for Indian coal-fired power plants may be decades away, the changing economics of different technologies may accelerate their retirement.

5.3 Projecting utilisation of coal power plant

Indian power stations are designed and incentivised to operate at the normative PLF of 85% (Shrimali, 2021). In 2021, only coal plants in the Eastern region achieved a PLF exceeding 80%. CEA's most recent planning assumption is that the average PLF will be 60.2% by 2029–2030 (CEA, 2023c), from 62.9% in 2022, and it recommends the net addition of 24,680 MW of coal (26,900 new plant less 2,121 retirement). As the share of variable renewable energy in generation rises, the system generator schedules the use of coal-based generation when solar and wind are unavailable (given that they have zero marginal cost). Figure 8 shows how coal's PLF will continue to fall as renewables are adopted and coal is forced to de-ramp during daylight hours. The Northern regions results are surprising, and the developers of the PIER model have identified it as an issue for further investigation.

Our analysis (for methodology see Section 4) suggests that, across India, the utilisation rate of coal drops from 58% in 2021 (much lower than the normative PLF) to 44% by 2031, and hovers here thereafter as investment in coal slows. If there are breakthrough technologies in short-term electricity storage, this could fall even lower. **The projected reduction in utilisation rates of the existing coal capacity is a major source of financial risk to lenders to the thermal power plant, even in the most conservative NDC scenario.** In the NZ scenario, the PLF drops to 10% from 2035.

Figure 8 Regional plant load factors for coal-fired power stations



Source: NDC scenario modelled using PIER, NZ derived by authors

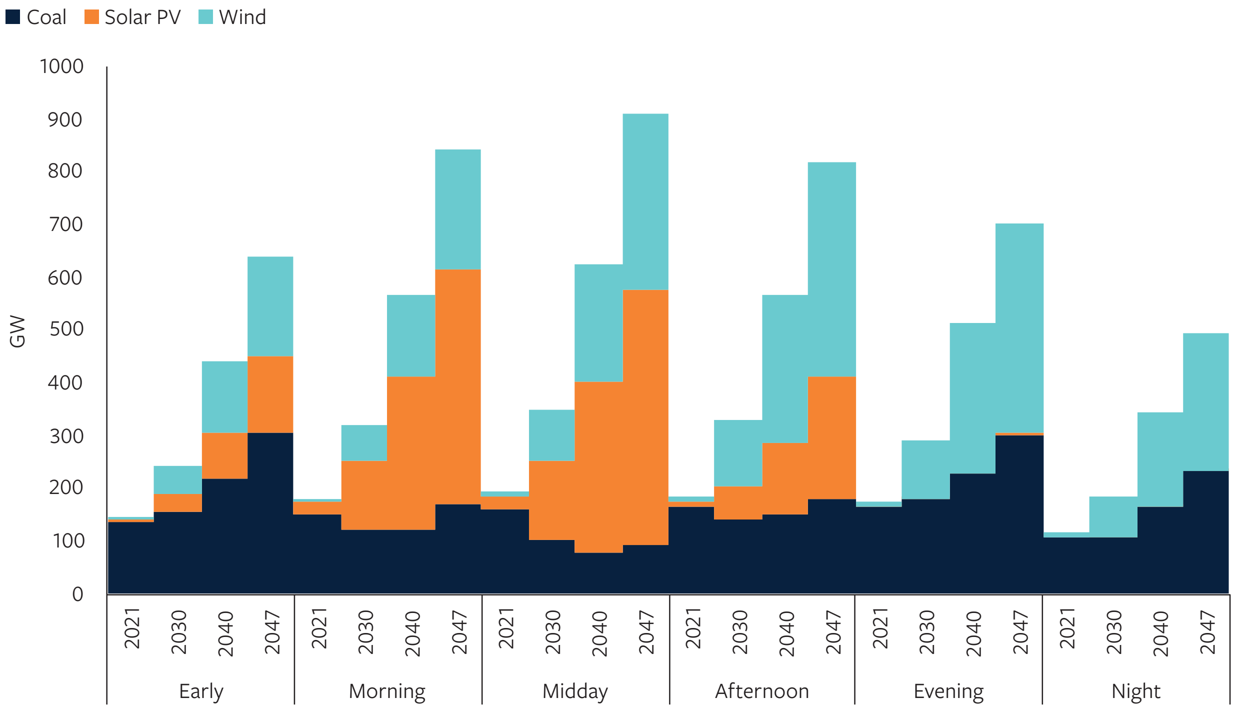
* NER excluded because of the small sample.

** PIER modellers identified that coal is used sparingly in NR and therefore project a low PLF. This issue is being investigated and is discussed in Appendix 6 paragraph 9 of their guidance note (Sreenivas et al., 2021).

Though the amount of coal-fired generation dispatched increases over time, Figure 9 shows this growth is not uniformly spread across the day. Demand between the morning to afternoon, from around 9am to 6pm, is fairly static between 2021 and 2047. But demand for 6am to 9am and for

6pm to 10pm rises very markedly, requiring some coal plants to operate with a dual daily peak. This unbalanced increase in coal demand makes the economics of investment in new coal plants harder and requires investment to make plants more flexible so that output can match the diurnal swing in demand. The scale of the daily swing becomes substantial: in 2021, it ranges between 40 GW and 60 GW (a 20 GW, or 50%, swing), but by 2047 it ranges between 34 GW and 111 GW every day (a 77 GW or 320% swing). **This has significant implications for thermal peaker plants, which have to be able to ramp up and ramp down their output to meet needs. It also has impacts for the system operator, which needs to ensure there is always flexible generation available to back up intermittent renewables. This means there may be an ongoing role for coal while alternate storage technologies mature.**

Figure 9 Power demand for selected years and technologies by day-slice for NDC scenario (GW)



Source: Authors modelled using PIER model

6 Impacts of transition on the coal value chain and financial institutions

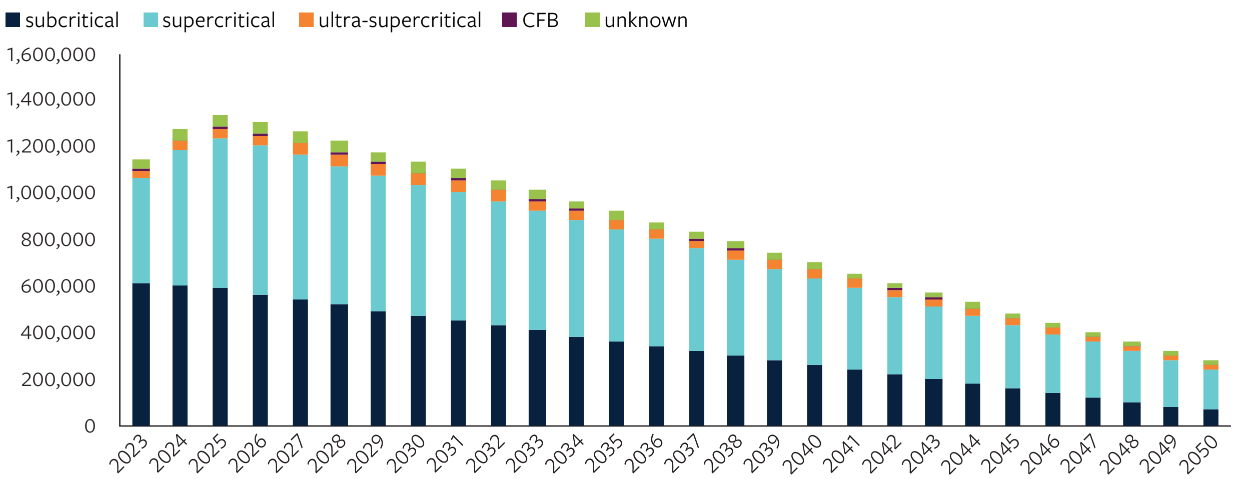
6.1 The value of coal assets on Indian balance sheets

This section calculates the current value of India's thermal power stations and their supply chains on corporate balance sheets. We then go on to analyse implications of the NGFS scenarios for the use of the capital embedded in power plants. We also briefly discuss the capitalisation of the power companies' value chain to understand its relative magnitude. These calculations will be useful to financial institutions interested in understanding their exposure.

Overall, we find that the power plants are worth ₹11 lakh crore, or $131bn. For more details on the methodologies used to identify and value India's coal power plants and the value of power plants in each state, see Appendix E. According to the Ministry of Statistics and Programme Implementation (MOSPI), the gross value-added by the electricity sector was ₹2.59 lakh crore ($30.9bn) in 2022–2023.

The asset value of thermal power stations is some four times the sector's annual contribution to GDP. This reflects the capital intensity and long-expected asset lifetimes. It also means that any significant early write-down of thermal power assets gravely damages the sector's solvency. Figure 10 shows the slow decline in value of today's stock of coal assets as well as the expected gradual shift in fleet composition from older subcritical power plants to newer supercritical plants as the oldest plant are eventually decommissioned. That said, newer supercritical plants make up only half the asset value in 2044. This overhang of coal assets arises from the huge construction boom of thermal plants between 2010 and 2019, when 147 GW of plants was built (62% of today's stock).

Figure 10 Residual value of thermal power stations by technology (2020 ₹ crore)



Source: Authors calculated from Global Coal Plant Tracker 2024

6.2 Value of assets owned by firms in coal value chain

As well as power generation, there are other firms in the supply chain that rely on coal-fired electricity producers as their primary customer. These include coal mining (particularly Coal India Ltd), Indian Railways and ports dedicated to coal shipping.

Table 2 shows the value of the coal assets of these sub-sectors. The total value of ₹3.20 lakh crore ($38.2bn) is around a quarter of the current value of the power stations. This represents a smaller systemic risk to the banking sector than coal-fired power generation, but the coal mining assets are concentrated in just eight states in the centre and east of India, particularly Jharkhand, Odisha, Chhattisgarh and Bihar, where Coal India Ltd has large direct and contractor workforces.

Table 2 Value of coal-related assets in the power sector supply chain, 2021 or 2022

	Total assets (₹ crore)
Railways	248,299
Mines	69,524
Ports	2,912

Source: Annual Reports Coal India Limited, Indian Railways and Adani Ports
Notes:
a. Railways based on coal as a share of freight-km and earnings from coal as a share of revenue applied to Indian Railways' balance sheet value (Indian Railways Annual Report 2021/22)
b. Mines based on power sector's share of coal purchases applied to March 2022 balance value of assets
c. Ports based on Adani Ports' imports of thermal coal as a share of its freight handled, adjusted for its share of thermal coal imports (Economic Times, 2019) multiplied by its assets value

6.3 Tariff structures and the allocation of transition risks

What would be the financial consequences of the more rapid drops in utilisation of the power stations projected in the NZ scenario, or even the DT scenario?

The three scenarios all project substantial growth in electricity demand and a continued role for coal, but the share of coal in power generation differs markedly. The NZ scenario assumes a steep decline within a few years, the DT scenario forecasts a delayed decline and the NDC scenario projects slight growth on average but with some regions experiencing drops. As we saw in Figure 8, India's average PLF drops from 0.58 to 0.44 in the decade after 2021, with larger drops in south (0.63 to 0.41) and west (0.65 to 0.49) because of these regions' rapid uptake of renewables.

The off-taker contracts between the generators and DISCOM contracts create incentives to use less efficient coal plants. Ganesan and Narayanaswamy (2021) describe some of the perverse outcomes arising from the vintage of contracts between generator and off-takers. They note that plants younger than five years old make up 25% of capacity but contribute only 19% of generation, while plants older than 10 years make up 35% of capacity yet contribute 38% of generation, despite their poorer efficiency. This inversion of the merit order arises because states schedule firm take-or-pay contracts ahead of low marginal cost new contracts in times of medium demand. Some older plants, despite being thermally inefficient, have low variable costs because they are located near to a pit head. While this might be financially cost-effective, it is environmentally undesirable if the additional burdens of air pollution and climate are included.

The changes outlined above, particularly the rules to determine whether a plant is 'available' and therefore eligible to be paid for its fixed costs, complicate the allocation of transition risks. These complexities are exacerbated by the fact that tariff structures vary depending on when contracts were signed, and whether the plant is owned by central government, state government or private actors. It is beyond the scope of this paper to disentangle exactly how these risks are allocated between the different parties, as individual loan and power purchase agreement documents will need to be studied, but lenders will need to take account of this issue when undertaking climate risk analysis.

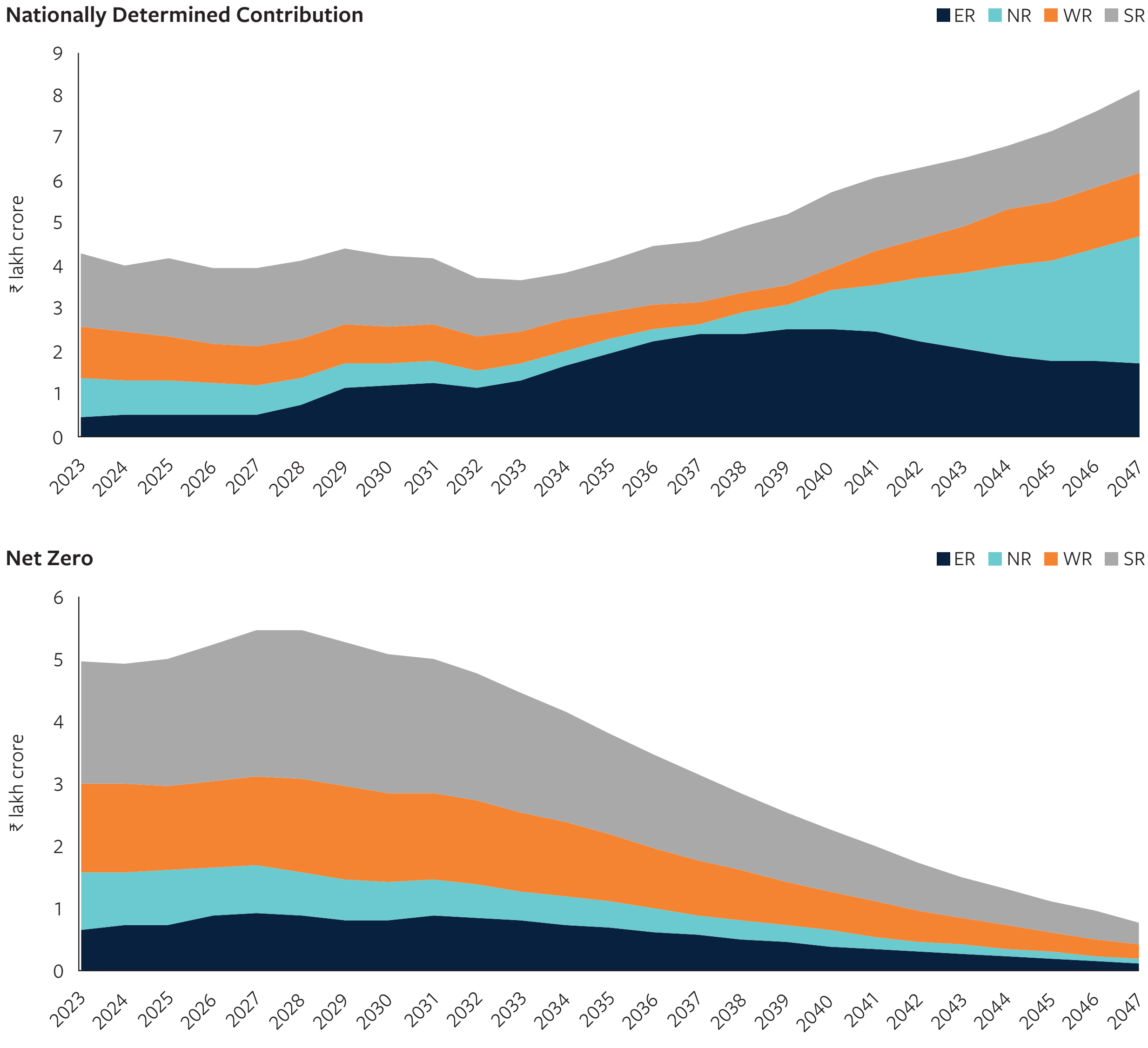
6.4 Value of underutilised coal generation assets

In Section 5, we saw that the PLF of India's thermal plants, already considerably lower than the normative target of 85%, falls further as renewable capacity grows. In Figure 8, we saw that it is projected to fall below 50% by 2030 even in the most conservative NDC scenario. In the NZ scenario, the PLF drops to around 20% by 2031 – a radical deterioration in the plant's viability.

Figure 11 recasts the impact of this reduction in PLF in terms of the increasing value of coal assets that are *not being used* in the NDC and NZ scenarios. This value was calculated by integrating the pre-2023 built plants' residual value if they depreciate in line with their scheduled decommissioning dates with the PLF changes for the two scenarios.

There is a sharp rise in underutilised coal assets from ₹3.9 lakh crore ($46bn) in 2026 to a sharp rise from 2033 to ₹8.1 lakh crore ($96bn) by 2047 as newer coal plants come online through hitting constraints in wind and solar additions. In the NZ scenario, the value of these 'stranded' coal assets peaks at ₹5.5 lakh crore in 2027 ($65bn) as the last coal-fired plant currently in construction starts operation, but quickly drops as new investment in coal ceases and the problem of stranded coal assets diminishes. By way of comparison, the RBI's most recent estimate of the current level of non-performing loans is ₹1.3 lakh crore ($15.5 billion), mainly owed to public sector banks (RBI, nd).

Figure 11 Book value of the non-utilised coal plant in constant 2023 prices (₹ lakh crore)



Source: Authors calculated from Global Coal Plant Tracker 2024 and PIER

How the risk from the overhang of underutilised coal assets manifests in the real economy is hard to predict. See Appendix D for further discussion. The boards either pass these costs to customers in the form of higher electricity prices or absorb losses until they are ultimately bailed out by state or national government. Let's see what happens under these two scenarios.

The gross output of the electricity sector was ₹14 lakh crore ($166.7bn) in 2022–2023[6] (MOSPI, nd). If the cost of servicing the debt is around 10%, the capital charges on underutilised assets could add ₹0.82 lakh crore ($9.8bn), increasing power prices by 6% every year. Appendix E lists the corporates with the greatest exposure to coal debt for the consideration of financial institutions.

6 ₹7.54 lakh crore in constant 2011–2012 prices converted to 2022–2023 prices using GDP deflator.

States already heavily subsidise electricity sales. In 2022–2023, 9% of state receipts were spent on power subsidies for losses made by DISCOMs for below price electricity sales (PRS, 2023). The cumulative debt of DISCOMs was ₹6 lakh crore ($71.5bn) in March 2022. The losses of confronting the capital costs of underutilised thermal power plant could double DISCOMs' stock of debt.

The PFC is the NBFC that refinances loans to the power and mining sectors. In its most recent annual report (PFC, 2024: p. 272), it shows loans in India of ₹9.97 lakh crore ($119bn), split 85% to 15% across the public sector and the private sector. Interestingly, the report notes that only ₹4.58 lakh crore ($54.5bn) are secured by tangible assets, demonstrating the low book value of the actual physical assets. This is the reason why the PFC can maintain its excellent credit rating and can be sanguine about transition risks: banks and governments have provided guarantees of ₹4.13 lakh crore ($49.2bn) protecting the financier. Its loans to the private sector also stipulate letters of credit, charges on the assets, debt/equity ratios and pledges of collateral as security. Nonetheless, the PFC identifies significant impairment of its loans to the power sector value chain. Around 6% of loans to generation and 4% of loans to renewables are impaired.

The PFC plays an important role reviewing the financial performance of DISCOMs, generators and other players in the power supply chain (PFC, 2024b), It documents the continued and structural distress faced by the DISCOMs. Debt rose from ₹0.74 lakh crore ($8.8bn) to ₹1.13 lakh crore ($13.5bn), with operational losses doubling from ₹0.11 lakh crore ($1.3bn) to ₹22,000 crore ($2.6bn). The losses arise from inability of utilities to pass on fuel cost increases, weaknesses in collecting bills, arrears in collecting subsidies from central government and distribution losses. This situation is exacerbated by DISCOMs' unwillingness to raise tariffs for household consumers: many consumers, especially the poor, pay below-cost tariffs cross-subsidised by industry, but DISCOMs already have a poor track record of delivering improvements in many states and are therefore unlikely to win voter consent for higher tariffs (Dubash et al., 2018). Rather than press the issue, then, DISCOMs or generators have taken a loss. This has constrained investment in the past, as generators have been unable to finance the air pollution retrofits to their plants by charging consumers more (Ganesan and Narayanaswamy, 2021). The situation is likely to get worse, too, if – as noted in our interviews – industry increasingly moves away from open access to captive power generation, removing the source of households' cross-subsidy.

The disuse of thermal assets and wholesale reduction in PLFs outlined above implies unprecedented pressure on balance sheets. Even generators whose balance sheets seem healthy will not be immune to such changes, and therefore investors and lenders will be exposed. Further research would help decipher this exposure more precisely, but even a brief look at NTPC and Adani Power (again, the two large operators with the healthiest debt-to-equity ratio) shows that it will be significant. Adani Power has just restructured its local currency loans into one facility of ₹19,700 crore ($2.4bn), with a partnership of investors led by SBI, which makes up 57% of total Adani Power borrowings in 2024 (Adani Power, 2024). NTPC's total liabilities were significantly larger, at ₹3.1 lakh crore ($37.2bn), of which 20% were bonds and 34% were local currency bank loans (NTPC, 2024). It may be, given the strength of their balance sheets, that these two generators will be among the last to be affected. Nevertheless, this highlights a risk that – in some scenarios – may become real within years.

6.5 Managing transition risks through flexible coal capacity

A key issue for assessing transition risk is judging how India's coal fleet will respond to the challenges outlined above. Highly flexible plants could be operated profitably by taking advantage of the volatile power spot markets that will reward plants that ramp up quickly. Plants that cannot operate under these market conditions face the risk of closure or underutilisation. Both early closures and sustained low PLFs are a potential source of transition risk to lenders.

Not all plants can be used flexibly. CEA notes that older subcritical coal plants are poorly suited to flexible use, though some of our interviewees disputed this, suggesting that some older plants can be retrofitted to allow flexible use. Such additional investments may be justified for these and younger plants with many years of operation remaining. The literature suggests there is also scope to deploy these power plants more flexibly without further investment (Power System Operation Corporation, 2020). Operators in Australia and Germany, where intermittent renewables are displacing coal even faster, have navigated these challenges for years; indeed, Australian coal plants are being retired early (Sharma and Loginova, 2024). New supercritical coal plants have been introduced that are more efficient than subcritical plants but more flexible. Moreover, the composition of the coal fleet is not the only consideration: a key transition risk is that other disruptive technologies – such as cheap and efficient batteries – may emerge that make the economics of coal still less favourable.

Singh and Tongia (2021) advocate for a multipronged approach involving decommissioning older plants, fitting newer plants with flue-gas emission control systems (for air quality) and investing in measures and practices to improve the flexibility of the fleet. The paper argues such tactical decommissioning could also address the excess coal capacity that has resulted in low PLFs. However, the paper points out some of the contracts enjoyed by the older plants require them to be dispatched ahead of other power plants even if their variable costs are high. The authors also note there is no simple law decreeing that newer plants are more efficient than older plants; indeed, some new plants use expensive imported coal, making their variable costs high, and well-maintained old plants can operate efficiently.

Ganesan and Narayanaswamy (2021) similarly propose that 30 GW of the older, least efficient capacity could be decommissioned. Their list overlaps with the list of plants that need flue-gas desulphurisation to comply with air quality regulations. The authors note their plan is hard to implement because the 'Indian power system is mired in a rigid set of bilateral contracts.' Interestingly, the list of underutilised, but efficient, assets includes many new privately owned plants. As Ganesan and Narayanaswamy note, the older plants have higher published ramp rates than the newer plants, which implies either that they have favourable contracts or – more problematically – that the newer plants may be less suited to help smooth a power system that relies heavily on variable renewable generation.

The data assembled in PIER have average information on some of these critical parameters, but ultimately the modelling needs to inform political, regulatory and commercial decisions, given the impact on regional jobs, state-owned enterprises (and their liabilities) and power engineering characteristics of plant and the local distribution grid.

7 A just transition out of coal

The global phase-down of coal is driven primarily by the urgent need to reduce greenhouse gas emissions and thereby limit the extent of climate change. India has an important role to play in this endeavour as the third largest emitter today (although its cumulative and per capita emissions are low relative to other major economies). Curtailing the average global temperature increase is also in the national interest, given India's high vulnerability to climate-related risks such as extreme heat, floods, storms, water scarcity and food insecurity (Mohanty and Wadhawan, 2021).

The decline of coal will offer many local benefits as well. Foremost among them is the scope to tackle air pollution, the cause of chronically poor respiratory health across much of the country. Exposure to air pollution accounts for nearly a million deaths every year in India, with coal-fired power generation primarily accounting for around 43,600 of those deaths (Singh et al., 2024). A handful of lignite-burning power plants in the Southern region are disproportionately responsible for these deaths, mostly because their location near dense population centres leads to higher exposure rates. Such factors can inform just transition planning: around 3.4% of generation capacity accounts for around a quarter of the cumulative marginal mortality (ibid.), so decommissioning these power plants early may yield outsized if non-monetised benefits.

While there are global and local benefits to a cleaner power system, the phase-down of coal power in India has the potential to adversely affect a range of different groups, in the absence of careful planning and supportive policies and investments. Vulnerable groups include workers in the coal industry, their families and communities; low-income electricity consumers and train passengers; and any households or firms depending on public services in states with higher economic dependence on the coal industry.

A total of 337,400 miners are formally employed in India's coal mines, with up to four times as many working informally (Tate et al., 2023). These jobs are not distributed equally across the country. India's coal deposits are heavily concentrated in three states in the Eastern region – Odisha, Jharkhand and Chhattisgarh (Ministry of Coal, 2023); another Eastern state, West Bengal, has 70,800 coal miners in formal employment (Tate et al., 2023). Thousands more people work in coal-fired power plants and coal transportation, although these jobs are spread more evenly across the country. The vast majority of these workers are men (Guimbeau et al., 2020).

The phase-down of coal power is likely to lead to job losses across the industry, as fewer workers are needed to meet falling demand. The affected workers and their families face a loss of income and sense of identity. The geographic concentration of coal mines means that specific towns and states will bear the brunt of these job losses. Moreover, if coal is the major employer and source of public revenues for a region, its decline will affect other local businesses and government-funded social services. Jharkhand, for instance, depends on coal royalties for over a quarter of its non-tax revenue; Chhattisgarh for almost a fifth (Mitra et al., 2023). Although men are likely to bear the brunt of the direct job losses, women will also bear the consequences through these indirect channels. For example, women living near mines tend to have more education and better health, which together contribute to greater personal freedoms and influence over household decisions (Guimbeau et al., 2020). The phase-down of coal and the associated decline of social services may therefore exacerbate gender inequalities. Thus, coal phase-down is likely to cause wider economic distress and affect community wellbeing.

The adverse impacts of the energy transition on workers, their families and communities can be managed through far-sighted planning for a just transition. National, state and local governments can work with key state-owned enterprises – Coal India Ltd, Indian Railways, NTPC and others – to mitigate the worst impacts in coal-dependent regions. Enabling policies and investments can stimulate economic diversification in coal-dependent regions, while providing retraining and re-skilling to former coal workers can enable them to find new employment or pursue entrepreneurial alternatives. Such efforts can help reduce political backlash against coal phase-out, enabling a faster, fairer and more orderly transition that minimises risks to both the financial sector and public budgets. Resources also need to be made available for the decommissioning of coal-fired power plants and rehabilitation of mines, so that former mining communities do not have to endure a legacy of unused brownfield sites and pollution after the operational life of coal assets comes to an end.

The decline of the coal industry may have other adverse impacts on economic opportunity and social inclusion in India, if not carefully managed to ensure a just energy transition. Many households and micro-, small and medium enterprises in India depend on the low cost of electricity to make ends meet or to break even. The shift towards renewable sources may lead to a lower levelised cost of electricity over the lifetime of the new generation capacity, but it is also likely to demand increased investment in transmission, distribution and storage, given its intermittent nature. Low-income consumers and smaller enterprises therefore face risks associated with higher electricity prices. The inability or reluctance to renegotiate old contracts and tariff structures means DISCOMs are unlikely to take advantage of more efficient and cheaper generation technologies (whether newer coal plants or renewable alternatives), and are saddled with significant liabilities (Vipra, 2024) that constrain their ability to manage the transition. In Tamil Nadu and Rajasthan, the outstanding debt of the state electricity board equates to 6% of the state's GDP (ibid.). However, while the financial risks to DISCOMs (and the state governments that own them) are high, the risks to consumers are relatively low: state governments have proven unwilling to pass on higher electricity costs, as Section 6.3 discussed.

A similar challenge faces the rail sector. In 2017, over 60% of the coal used to generate grid electricity was transport by rail. Coal accounted for 44% of Indian Railways' freight revenues and even more of its profits (Kamboj and Tongia, 2018). Coal therefore significantly cross-subsidises passenger transport by rail. If the volume of coal freight diminishes, Indian Railways will have to increase the explicit over-pricing of coal (making coal a still less economically competitive option and accelerating its phase-down), seek larger subsidies from the central government or increase passenger fares. The last of these options is possible as India has some of the lowest passenger fares relative to freight charges in the world (ibid.) but will be politically unpopular. It will also disproportionately affect lower-income groups and internal migrants. Indian Railways and the central government can help manage these wider risks and ensure a just transition through incrementally adjusting pricing policies and shifting capital investment to prioritise the needs of passengers and other industries, rather than the transport of coal, despite its current profitability.

Many subnational governments and state-owned enterprises are already preparing for a future with a diminished role for coal. Jharkhand has established a just transition task force to announce a roadmap for the coal-dependent state by December 2024; Coal India and NTPC have announced plans to diversify their activities.

From the perspective of the financial sector, Selvaraju et al. (2024) identify three levers that investors can pull to support a just transition:

- Encourage companies to use the homegrown disclosure framework, the Indian Business Responsibility and Sustainability Reporting, to ensure their own portfolios are aligned with a just transition.
- Allocate more capital towards the just transition by buying and holding India's green, social, sustainable and sustainability-linked bonds.
- Support companies to integrate just transition principles into their plans and financing strategies.

8 Key findings and implications

8.1 Key findings

India's goal of achieving net zero emissions by 2070 goal implies rapid transformation of the power sector. Although India has spent the past decade building out its coal-fired power fleet, solar PV is now the cheapest source of electricity. Combined with wind and battery storage technology, whose prices are also falling, renewables offer a 24-hour alternative that looks set to dominate India's future electricity supply even in the conservative NDC scenario. The economics of clean technology are simply too compelling. As a result, the following transition risks loom.

The PLFs of coal-fired plants are already low and are projected to drop further even in the conservative NDC scenario. In our modelling, we quantify the underutilisation of coal, which we see as a key transition risk facing the electricity sector. Coal generation will increasingly be used to meet peak demand rather than provide baseload power. Much of the existing thermal fleet will become redundant as renewable capacity surges, owing to a combination of declining demand for coal and an inability to ramp up in response to peaks in demand. The average PLF of coal is already low at 58.5% (the ideal would be around 85%; Shrimali, 2021). In the NDC scenario, as Table 3 shows, we find that it drops to 47% by 2030 owing to displacement by solar PV during daylight hours. The average PLF drops below 25% in the same year in the NZ scenario, and below 10% by 2035.

Table 3 Projected PLFs for selected years for NDC and NZ scenarios

	2025	2030	2035	2040
NDC	56%	47%	46%	45%
NZ	43%	24%	8%	6%

Source: Authors' modelling

Current incentives may lead to inefficient coal phasedown pathways. Peaker plants are still needed for back-up to fast-growing solar so, until long-term storage technologies mature, India will need to adapt and retain some thermal plants to complement intermittent renewables. Some plants are more suited for adaptation to rapid ramp rates, but short-term financial incentives like fixed tariffs may lead to older plants being prioritised. The other alternative, of keeping all existing and under-construction thermal plants on standby until their planned retirement dates, will impose substantial financial risks relative to the gross value-added of the sector.

India faces high risks of stranded assets in the coal sector, and delaying the phase-out of coal massively increases these risks. The fleet of coal-based thermal power stations is relatively young, and planned retirement dates are for the most part decades away. The pace of the renewable energy transition means that many thermal plants will become effectively inactive long before then. There is a sharp rise in underutilised coal assets in the NDC scenario, from ₹3.9 lakh crore ($46.4bn) in 2026 to ₹8.1 lakh crore ($96.5bn) by 2047 as newer coal plants come online through hitting constraints in wind and solar additions. In the NZ scenario, the value of these 'stranded' coal assets peaks at ₹5.5 lakh crore ($65.5bn) in 2027 but quickly drops as new investment in coal ceases and the problem of stranded coal assets diminishes. By way of comparison, the RBI's most recent estimate of non-performing loans is ₹1.3 lakh crore ($15.5 billion), mainly owed to public sector banks (RBI, nd). Coal-fired power in India therefore faces very substantial near-term transition risks even in the conservative NDC scenario.

These sums are substantial (around four times greater than the sector's value-added), but short-lived and much lower in magnitude than if more coal plants are added to the stock. It is therefore cheaper to achieve a rapid transition, even if this brings short-run higher transition risks.

Despatch of coal-fired electricity is not environmentally or financially optimal. Whether or not a power station is scheduled by the system operator is often not determined by the thermal efficiency, carbon emissions or fuel cost of the plant but by the nature of the contract between the generator and the DISCOM. This means the system operator sometimes schedules older, dirtier plants with two-part tariffs or take-or-pay contracts ahead of new, efficient plants that have to recover their full economic cost, and does not fully reward necessary characteristics like flexibility needed for the transition.

The off-taker contracts that generators sign with DISCOMs mean that the costs of financing unused thermal power stations' fixed costs are often borne by DISCOMs. This exacerbates their financial stresses, and likely hampers new investment in renewable energy because financially precarious DISCOMs are unable to pay generators on time, invest in connecting new renewable capacity or bring on technologies like smart grids, electric vehicle charging stations and large-scale storage.

NGFS scenarios are a start but are not enough. They helpfully inform the development of decision-useful scenarios, but they need augmenting to model India-specific transition risk. The NGFS models do not handle stranding well because there is no explicit modelling of the stocks of lumpy assets like power stations or coal mines that sit on balance sheets and are the source of major transition risk. We found the current value of power plants to be ₹11 lakh crore and mines, coal-railway and coal-ports another ₹3.20 lakh crore. NGFS is also not designed to account for the numerous country-specific assumptions and constraints to the transition, such as the limits on the rate of deployment of new assets, electricity storage and transmissions of power, that are needed to enable the modelling of energy futures.

8.2 Considerations for financial institutions and the RBI

The RBI disclosure guidelines (2024) invite financial institutions to develop strategies covering:

> 'the identified climate-related risks and opportunities over short, medium and long term; ... risks and opportunities on the RE's [Regulated Entity's] businesses, strategy and financial planning;... the resilience of the RE's strategy taking into consideration the different climate scenarios.'

There is a high risk of stranded assets in India's coal sector, and currently available risk assessment methods are not capable of fully recognising this. This section lays out considerations for different actors within the financial sector to enable them to effectively engage with these challenges.

Financial institutions

- Start exploring exposure to stranded assets and other transition risks immediately, without waiting for RBI regulation. Clear guidance on disclosure and methods is important to ensure standardisation and enable comparisons across the sector, but engaging with the challenges now will enable rapid application of risk management when the guidance comes. This is especially important given the pace of transition in some scenarios.
- Carefully analyse the downside risks in investing in any new generation assets vulnerable to transition risks, particularly low PLFs and technological/price shifts like cheap power storage. Two banks, Federal Bank and Suryoday Small Finance Bank, have already committed not to do so, according to the Unprepared survey in 2022 (Asapur and Fernandes).

PFC

The PFC plays a role in reforming and restructuring DISCOMs, reporting on their performance (PFC, 2024c) and financing their efforts. It could play a similar role elsewhere in the system. It is also highly exposed to these transition risks, with some ₹10 lakh crore of loans to the sector. Given the importance of its mandate and the centrality of its position between ministries of power, coal and rail, it could make the following strategic changes to reduce the system balancing costs and contribute to a swift but orderly transition:

- Review and rationalise off-taker contract arrangements between generators and customers and a financial package to exit from contracts with perverse incentives, such as maintaining inflexible old thermal plants in operation.
- Finance a Just Transition package of measures to create alternate employment opportunities in mining communities.
- Fund innovation in DISCOMs to hasten the adoption of decentralised electricity generation and vehicle-to-grid bidirectional flows of power between customers and DISCOMs.

RBI

These transition risks have important implications for the RBI because higher electricity prices create direct and indirect inflationary pressures, electricity being an important component of consumer spending and a crucial input throughout the economy. Higher prices could also have a material impact on states that are liable for losses made from the DISCOMs if cost increases from the underutilised thermal plants are not passed on to consumers and are instead borne by the state government, affecting its credit rating and access to more borrowing. The following considerations could support the orderly management of these transition risks:

- Develop a plausible set of scenarios for India, drawing on NGFS work, to be standardised for scenario analysis across the financial sector. These scenarios should contain:
  1. specific policies that the Indian government might adopt in these scenarios, for example on the proportion of non-fossil fuel capacity as a share of total Indian capacity
  2. realistic assumptions about the operation of the electricity sector, like within-region and intra-annual granularity of supply and demand
  3. in consultation with ministries, standardised assumptions for key parameters like price evolution of renewables and storage, and constraints on the adoption of renewables.

- Ask NBFCs like the PFC to engage with borrowers (coal mines, DISCOMs, generators) on systemic inefficiencies arising from failure to decommission inefficient or unused plants, simultaneously relieving DISCOMs of burdens of legacy contracts with out-of-date take-or-pay or two-tier clauses.

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Appendix 1 Questionnaire for key informant interviews

NGFS has developed seven scenarios based on different assumptions about mitigation risks, the extent of international coordination and the severity of physical risks, using teams of international modellers.[7] We are using three of NGFS's seven scenarios (NDC, NZ and DT) to assess transition risks to FIs lending to companies operating coal-fired power stations and their supply chain. Scenario selection was guided through a discussion with the RBI.

The NGFS datasets contain India-specific projections for many variables to 2100, including electricity demand, electricity installed capacity, coal installed capacity and renewables installed capacity.

We propose to use these data points to anchor the capital values data we have assembled to project the values of the capital stock invested in coal power and its supply chain, to potentially introduce some regional disaggregation and to consider how the transition risks may manifest. (The NGFS models assume a carbon tax for global modelling, which is unlikely to be the way that India reins in coal-fired power.)

Before extending the datasets to include asset values of coal power and its supply chain, we are discussing the scenarios with experts to assess their credibility. We have not commenced any modelling work yet, and the data below are derived from the literature. We are particularly interested in understanding how any reductions in coal-fired power might be implemented – for example regionally, age-wise, air quality compliance – which could change the risks.

This note has been prepared to guide our interviews with experts. It includes key data extracted from NGFS scenarios and other datasets where they exist. Not all the NGFS scenarios output all the variables, and we are using GCAM, which has the most complete set of variable outputs, for our purposes.

Electricity demand growth

- How plausible is the continued growth in demand for power between now and 2047?
- What thoughts are there about the feasibility of the IESS47 NZ scenarios and the implications for coal?
- The NGFS scenarios propose a steep increase in electricity demand (a 10-fold increase between 2020 and 2100). Is this feasible? Likely?

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7 www.ngfs.net/ngfs-scenarios-portal/, models by GCAM by the Joint Global Change Research Institute, MESSAGEix by IIASA and REMIND-MAGPIE by the Potsdam Institute for Climate Impact Research.

Growth in installed capacity

- All NGFS scenarios project substantially more power capacity than IESS now and 2047 (up to double), is this likely or achievable?

Role of coal

- What do you make of the NGFS projections of new coal power station build and closure?
- Currently, IESS47 and the NEP assume a continued (albeit much reduced) trajectory for new build and capacity maintained for decades – does this accord with your projections?
- What policies might be used to reduce coal? Are there regional or technology issues?
- How much scope is there for coal power to be used flexibly to complement intermittent renewables? Any thoughts about ramp-up and ramp-down times?
- Any other technologies to extend coal use (biomass/carbon capture and storage/direct air capture/offsetting)?
- What issues might retard growth in renewable energy (land availability, grid, raw materials, finance)?
- What technologies can reduce coal power life?
- What are your views on short-term storage (four to eight hours)?
- What are your views on longer-term storage (two to three months)?

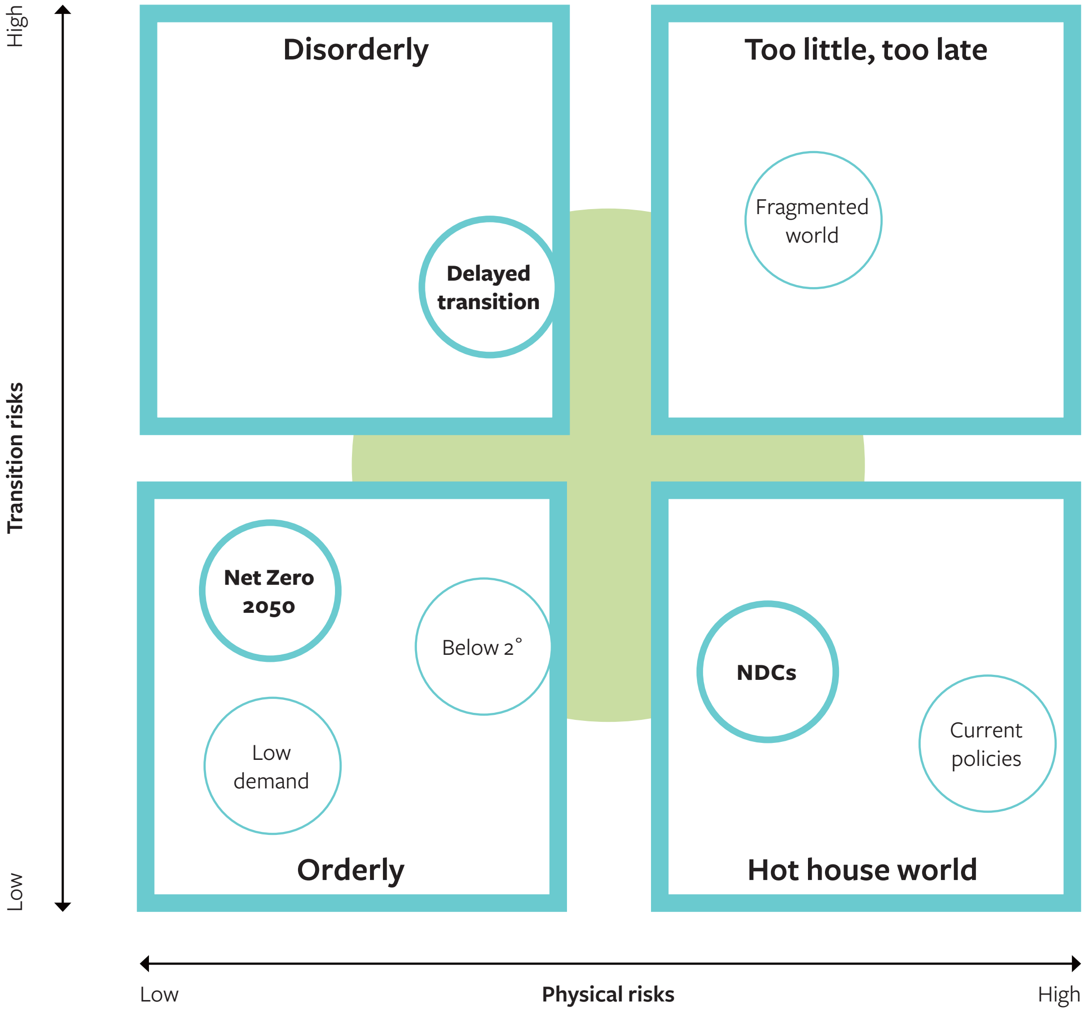
Transition risks for coal

- What other sectors of the economy are most vulnerable if demand for coal electricity falls sharply? Are these prepared for the transition?
- What risks are there that coal plants may be closed early (air quality, cooling water shortages, emissions trading)?
- What PLFs are considered uneconomic?
- Do the EU Emissions Trading Scheme and Carbon Border Adjustment Mechanism represent a significant risk to Indian coal?
- Which plant may be closed first (age and technology)?
- Are some coal technologies more flexible (subcritical, supercritical, ultra-supercritical)?
- NGFS modelling is undertaken at the whole-India level. Is it necessary to introduce regional disaggregation to allow for localised supply/demand issues?
- Will investment in interstate power transmission be sufficient to smooth out regional imbalances for surplus coal as renewable energy grows in some regions?

Appendix 2 Choosing between the integrated assessment models used by NGFS

NGFS identifies seven scenarios to assess climate-related financial risks to 2100. These scenarios, laid out in Figure A1, assume different levels of physical and transition risks depending on the speed and success of the transition. 'Hot house' scenarios, for example, expect high physical risks and lower transition risks to reflect a world in which global efforts at transition are insufficient and critical temperature thresholds are exceeded. Orderly scenarios, as the name implies, are controlled and fast, implying both low physical and low transition risks; disorderly scenarios are less controlled – albeit eventually successful – and therefore display higher levels of transition risk but lower levels of physical risks.

Figure A1 NGFS scenario quadrants

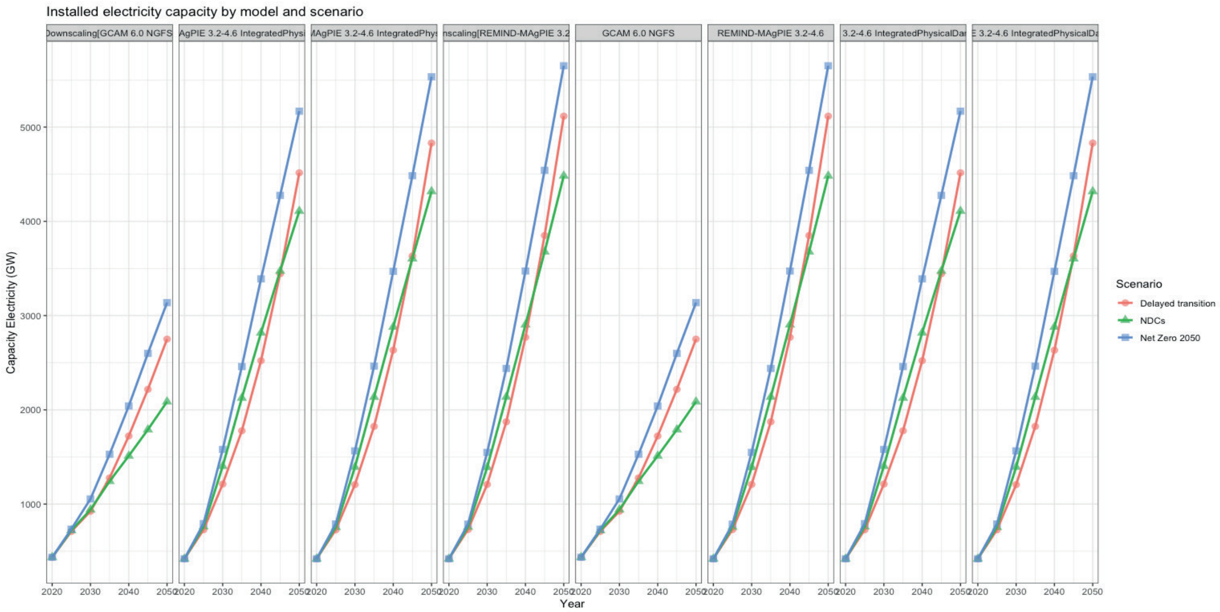


Source: Adapted from NGFS scenario explorer: https://www.ngfs.net/ngfs-scenarios-portal/explore

NGFS uses three integrated assessment models (IAMs) for each of the seven transition scenarios, reflecting the uncertainty inherent in projections over such time horizons. These are GCAM, REMIND MAgPIE and MESSAGE-GLOBIOM, all of which contain macroeconomic models that quantify the impacts of the scenarios on growth patterns, and which can be augmented by combining them with the NiGEM macroeconomic model. They share many similarities and some important differences, resulting in different projections for each scenario (Takkala et al., 2024).

All of the IAMs are global models, but they disaggregate differently at the regional level. GCAM has better resolution for the Indian context than MESSAGE-GLOBIOM: India is identified as a distinct subregion of the model, and, unlike most other countries, therefore does not require 'downscaling' to estimate national-level projections. At the same time, GCAM projects less ambitious acceleration of generation and capacity than REMIND-MAgPIE (see Figure A2). This partly reflects the inclusion in REMIND of physical damage feedback loops, which may be more useful in future modelling projections but are more likely to seem far-fetched in the current policy environment, given the existence of current government scenarios – as suggested in the interviews.

Figure A2 Comparison of NGFS IAM projections of installed electricity capacity



Source: Authors using NGFS scenario explorer (www.ngfs.net/ngfs-scenarios-portal/explore/)

Ultimately, the IAMs used to project the energy transition have to depict national policies and the stock of power stations in a stylised manner to make the data-gathering and policy simulation manageable. One of the simplifications made is to use carbon taxes as a proxy for all policies aimed at driving the replacement of fossil fuels with renewable energy sources. Another simplification is to abstract away from the stock of power stations owned by a country at the start of a modelling period and to largely ignore the book value and vintage of assets that is at risk of stranding. The IAM depiction also abstracts away from bottlenecks in transmission and distribution and treats electricity generation anywhere in the country as fungible.

These assumptions, while understandable in the context of a set of standardised scenarios for central banks to use as a starting point, are an incomplete representation of the true credit risks banks face. Our interviews suggested three main differences between the stylised NGFS assumptions and India's context.

1. India's fleet of a large number of young coal-fired power stations and their linkages with Indian financial institutions' balance sheets, as they are currently valued over long time horizons and hence are more susceptible to 'stranding' under early transition scenarios
2. faster growth in demand for power compared with investment in renewables and storage, which may mean an extension in the useful life of coal assets, especially if rollout is curtailed by workforce, locational or planning bottlenecks and
3. legal arrangements included in the off-take contracts between the thermal generators and the DISCOMs, which may transfer the risks to the DISCOMs instead of financial institutions and hence shield lenders. In such cases, the exposure to the transition risks may sit on the state government's balance sheets.

Appendix 3 Choosing among the energy models developed specifically for India

The NGFS Indian output needed to be adapted before it could be credibly used to develop useful climate scenarios for decision-makers. This is because the GCAM model does not contain country-specific detail about the age and location of India's power generation assets. Instead, GCAM derives capacity projections from its electricity supply projections, using capacity factors specific to technology (in this case, differentiated between seven grades of coal) and region (India) (JGCRI, 2021).

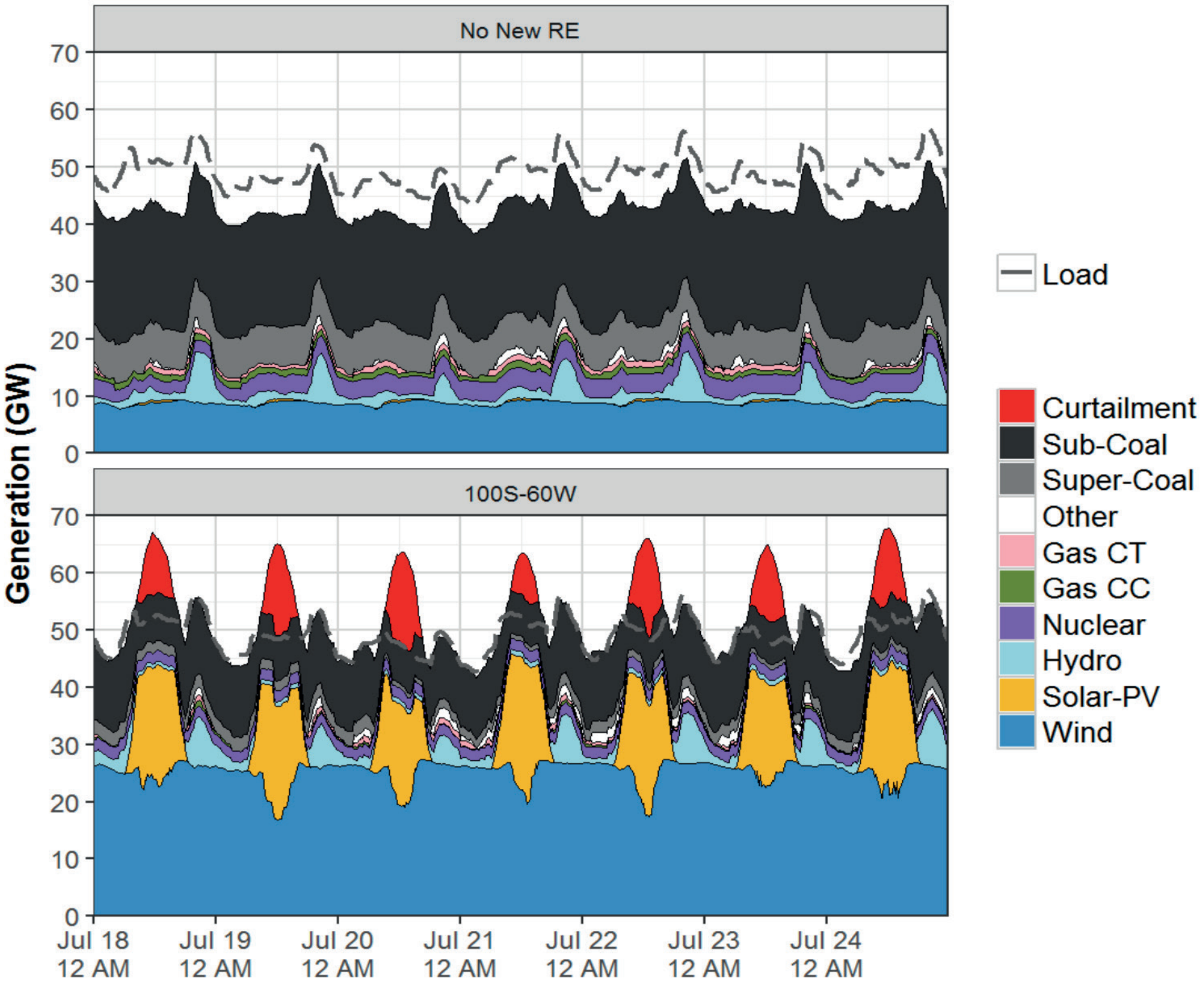
India has several high-class energy and electricity models developed by government, academia and think-tanks. These models provide greater granular detail for individual regions and states and better capture local circumstances, such as the age of Indian thermal power plants, than do the NGFS IAMs.

Researchers at CSEP (Takkala et al., 2024) compared 10 Indian energy system models. These included international models like GCAM, REMIND and MESSAGEix-GLOBIOM used by NGFS, where India is a region within the global model. Three models have been written by Indian teams as stand-alone models: the Excel-based IESS47 by the government's Niti Ayog, Rumi/PIER by the Pune-based think-tank Prayas-Energy, and Energy Policy Simulator (EPS) India adapted for India by World Resources Institute (WRI)-India and Energy Innovation LLC.

The 10 models were created for different uses and have different strengths and weaknesses. Some focus solely on the energy system; others include land-use change or the interaction between climate change and the energy system, for instance via loss of hydropower resources. They differ in the level of regional detail. Importantly, for our purposes, there are substantial differences in treatment of the electricity sector.

As well as the models reviewed above, in 2017 the Lawrence Berkely National Laboratory in the US worked with the Ministry of Power to simulate the installation of 100 GW of solar and 60 GW of wind to attain the (then) target of 175 GW of renewables by 2022. They used their state-of-the-art power planning tool to model the Indian generation, transmission and distribution system, taking into account plant ramping/de-ramping and transmission bottlenecks. The outputs of the model for a simulated summer week in 2022 are shown in Figure A3. They reveal a significant need for curtailment every afternoon even after the coal power plant is ramped down. They infer that 46 GW of the thermal power could be retired with almost no adverse impact on the system, with an increase in the PLF of the remainder to 62% from 50%. They found that 10 GW of the thermal power was never despatched.

Figure A3 Despatch for the Southern region, 18–24 July



Source: Lawrence Berkeley National Laboratory (2017)

An ideal model would calculate the optimal mix of electricity generation technologies to meet India's growing demand for electricity over time, taking into account the characteristics of the electricity generation technology, like fixed and variable costs, and ability to flexibly meet changes in demand over the course of a day or for different seasons. Users should be able to edit the model to insert annual electricity demand and fossil fuel/renewable energy mix till 2050 from NGFS scenarios.

The following criteria were considered prerequisites for consideration.

- availability of the Indian calibration of the model: the model should already include Indian data in terms of electricity technologies, regions, pre-existing capacity of electricity generation, and sunlight and wind characteristics
- accessible programming language: this excluded packages that needed proprietary licences, e.g. for GAMS or Vensim.

Table A1 also includes the IEA's model, as this model is widely used and referenced. It excludes the NGFS models, discussed elsewhere.

Niti Ayog produced an initial version of IESS model before the Glasgow Conference of the Parties in 2022. An updated version was published in July 2023; this contains scenarios till 2047 and can either be interrogated online or downloaded as an Excel spreadsheet. Results from the model are used across the government, unifying otherwise disparate models produced by different ministries. The model provides a good overview of energy demand and supply across the whole economy and users can vary assumptions. However, there is insufficient detail of the power sector.

WRI-India worked with energy consultancy Energy Innovation LLC to develop its downloadable system dynamics model (in Vensim), EPS. This allows users to manipulate different economic variables to simulate policy/economic changes on a range of different pollutants, GDP and wages. It is particularly suitable for transport modelling.

The IEA's Global Energy and Climate Model is widely used by governments and international bodies to produce reference scenarios for net zero, 'stated policy' and others. It is not available for independent researchers to use. The Indian government collaborated with the IEA during the production of the 2021 India Energy Outlook (IEA, 2021), which contains scenarios till 2040.

Prayas' Rumi India configuration is called Perspectives on Indian Energy using Rumi (PIER) and was used to model the Indian energy system in the 2020s (Prayas, 2021). A full version of the model, written in Python, is available on GitHub, though most scenario adjustments can be made by editing csv files. PIER's electricity model matches supply and demand, splitting India into five regions, and recognises five seasons and five representative time periods over the course of a 24-hour day. PIER is ideally suited for our purposes. It also contains information on the stock of power stations, including the decommissioning schedule for coal and gas power plants over the coming decade. Any premature retirement ahead of this schedule can be used as the basis for calculating asset stranding.

Table A1 Suitability assessment of Indian models for long-term electricity market projections

	Age-stock model of thermal power plant	Regionalised demand / supply	Seasonal and diurnal balancing	Customisable power sector (demand, technology)	Macro-economic integration / Climate Feedback
Niti Ayog – IESS	✗	✗	✗	✓	✗
WRI – EPS	✗	✗	✗	Some ✓	✗
Prayas: Rumi-PIER	✓	✓	✓	✓	✗
NGFS models	✗	✗	✗	Some ✓	✓
IEA – WEO	✗	✗	✗	✗	Some ✓

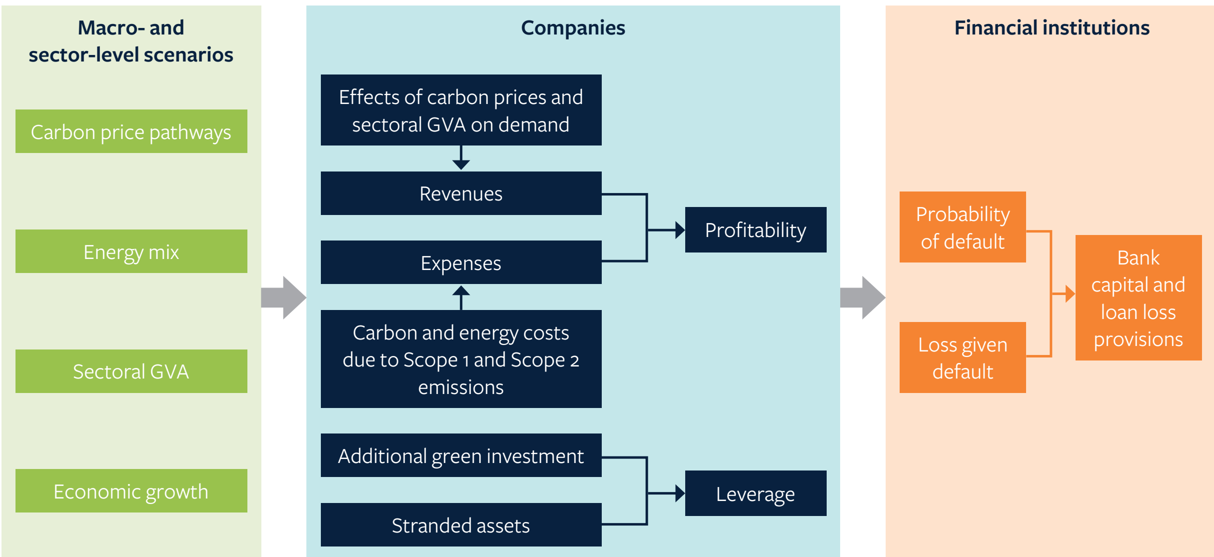
Source: authors

Appendix 4 Transition risks and the stranding of coal assets

Figure A4 shows the pathway through which real economy changes in macro- and sector-level electricity demand, energy mix and sectoral value-added are transmitted to specific companies, impacting their revenue and costs, and hence their profitability. Companies will typically finance their asset creation through raising equity or borrowing from financial institutions or bonds issued on the debt capital market. Borrowing is repaid from net annual proceeds once operating costs are recovered. When demand or revenue fall, companies' assets become 'stranded', meaning assets are underutilised and the net revenue is not meeting the capital repayment costs.

Companies face a number of transition risks, including new costs (e.g. carbon taxes), new investment (e.g. carbon sequestration equipment costs), bans (e.g. internal combustion engine cars) or low-carbon replacement (solar PV). Through their lending, financial institutions are exposed to these transition risks; the extent will depend on the risk of default and the company's leverage (i.e. the balance between risk-bearing cash, equity and financial institution loans).

Figure A4 From macro and sectoral variables to micro-level risks, examples of key transmission channels



Source: Dafermos and Volz, 2024

Discussions with experts and policymakers suggested it was unlikely that carbon pricing (or allowance allocation) would be set in a way to imperil the financial viability of coal fired plant. However, the rapid penetration of renewables, particularly solar PV, was seen as an obvious threat to coal-fired power plants.

If an asset risks stranding, companies can react in several ways:

- **Ignoring:** The value of assets declines, with liabilities remaining the same, leading to higher leverage, without coal companies reacting. This can directly increase the defaults of these companies. In Germany, the power utility RWE is shrinking because of its inability to react.
- **Transferring:** Coal companies pass the costs on to DISCOMs, which either face defaults or are supported by the government. The latter results in deteriorating fiscal deficits, leading to lower government spending. This can reduce growth, which can in turn increase defaults across the whole economy.
- **Business model change:** Coal companies change their business models and invest in renewables to avoid a decline in their assets. This investment needs to rely at least partly on debt, leading to higher leverage and thus to more defaults. In Denmark, Danish Oil and Natural Gas successfully switched from oil and gas generation to become Ørsted, the world's largest offshore wind company, with 90% renewable power capacity (Ørsted, nd).

To switch business model financial institutions must be prepared to lend to finance the transition.

Appendix 5 Modelling value of coal plants' transition risk and their incidence by state

Valuation of the coal plant fleet

The authors developed a bottom-up model to value the fleet of coal-fired power plants. The database was constructed from the Global Coal Plant Tracker January 2024 edition, issued by the Global Energy Monitor 2024. The database contains location, capacity, owner, combustion technology (mainly subcritical, supercritical or ultra-supercritical) and start year of coal power plants. The as-if-new value of each power plant was calculated for 2023 based on its size and technology using India-specific technology cost factors (CEA, nd). The current value in nominal prices was then calculated by first deflating it back to the year of construction and then writing off the value that has already been depreciated.

The residual value of the power plants in 2023 was calculated in three steps.

1. based on its size (GW) and technology – subcritical, supercritical and ultra-supercritical, from CEA (nd)
2. deflating the cost back to the year of construction to calculate the original (nominal) cost of construction, from the GDP deflator of MOSPI (nd)
3. using a straight line depreciation schedule over 40 years (India Code, nd) to calculate its remaining value.

Given that asset-level data are not publicly available, our methodology necessarily relies on many assumptions. We therefore cross-checked our calculated value of thermal power plants owned by NTPC (owner of 20% of India's coal thermal capacity)[8] with the value quoted in NTPC's consolidated balance sheet for 2023 (NTPC, 2024).

According to the database, there were some 845 coal-fired power stations in operation in India in 2024, including captive plants operated by industry. Table A2 sets out our estimates of the value of India's coal fleet at the state level.

We verified our approach to valuation by comparing our valuation with NTPC's reported valuation. Our estimate suggested that NTPC holds coal plants worth ₹2.2 lakh crore ($26.2bn), while the annual report values the plants at ₹2.39 lakh crore ($28.5bn), which will include assets other than thermal power plants.

8 Assuming that joint ventures are 50% owned by NTPC.

State-by-state valuation of the coal fleet

Table A2 Residual value of coal fired power stations in 2023 (2023 ₹ crore)

State	Subcritical	Supercritical	Ultra-supercritical	Unknown / CFB*	Total
Andhra Pradesh	26,461	41,715	–	4,967	73,143
Assam	5,454	–	–	–	5,454
Bihar	20,433	37,032	–	1,321	58,786
Chhattisgarh	90,668	40,140	–	2,875	133,682
Gujarat	30,659	41,695	–	5,705	78,059
Haryana	17,293	6,589	–	–	23,882
Jharkhand	22,397	6,715	16,476	646	46,234
Karnataka	11,297	35,297	–	–	46,594
Madhya Pradesh	59,184	39,750	9,997	12,953	121,884
Maharashtra	75,166	47,451	–	–	122,618
Odisha	64,794	22,326	–	863	87,983
Punjab state	6,670	19,813	–	–	26,483
Rajasthan	22,935	33,980	–	–	56,915
Tamil Nadu	40,216	10,211	–	16,421	66,848
Telangana	28,601	15,999	–	312	44,911
Uttar Pradesh	48,775	51,459	–	1,180	101,413
Uttarakhand	217	–	–	–	217
West Bengal	39,510	7,145	–	2,032	48,687
Total	**610,729**	**457,317**	**26,473**	**49,273**	**1,143,793**

*CFB – circulating fluidised bed
Source: Authors calculated from Global Energy Monitor 2024

Coal power corporates most exposed to transition risks

A brief overview of the balance sheets of the largest thermal power generators highlights the differences in their financial performance. The six largest owners in India, by capacity, are NTPC, Adani Power and the state generation corporations of Maharashtra, Tamil Nadu, Telangana and Rajasthan. These collectively account for 38% of India's thermal power capacity in 2024 (Global Energy Monitor, 2024). The annual reports of each provide varying levels of detail, which complicates balance sheet comparison.

Table A3 Top five thermal power generation companies in India, 2024

Owner	Capacity (GW)
NTPC	54.1
Adani Power	12
Maharashtra State Power Generation	10.2
Tamil Nadu Generation and Distribution	10
Telangana State Power Generation Corporation	8
Rajasthan Rajya Vidyut Utpadan Nigam	7.8

Source: Authors calculated from Global Energy Monitor, 2024

NTPC is by far the biggest player in the sector, in terms of both the capacity of the plants it owns and its capital structure. It also stands out for its relatively healthy debt-to-equity ratio, of 1.88. Adani Power has an even stronger ratio, of 1.14, but the state generation corporations are in more trouble: Maharashtra at 3.13 in 2022, Rajasthan at 10.77 in 2021 and Tamil Nadu at -2.08 in 2023 (Rajasthan Rajya Vidyut Utpadan Nigam, 2021; Mahagenco, 2022; Tangedco, 2023; Adani Power, 2024; NTPC, 2024). This is despite the transfer of costs from generation to DISCOMs through power purchase agreements and the fixed cost tariff system, which has long kept DISCOMs as debtors to generators (Ganesan and Narayanaswamy, 2021). The PFC is heavily exposed to these state generators: 93% of Maharashtra State Power Generation's outstanding debt in 2022 – roughly ₹24,000 crore – for example, was to the PFC or its subsidiary, REC (Mahagenco, 2022).