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# India’s Energy Transition: Implications and considerations

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## Acknowledgments

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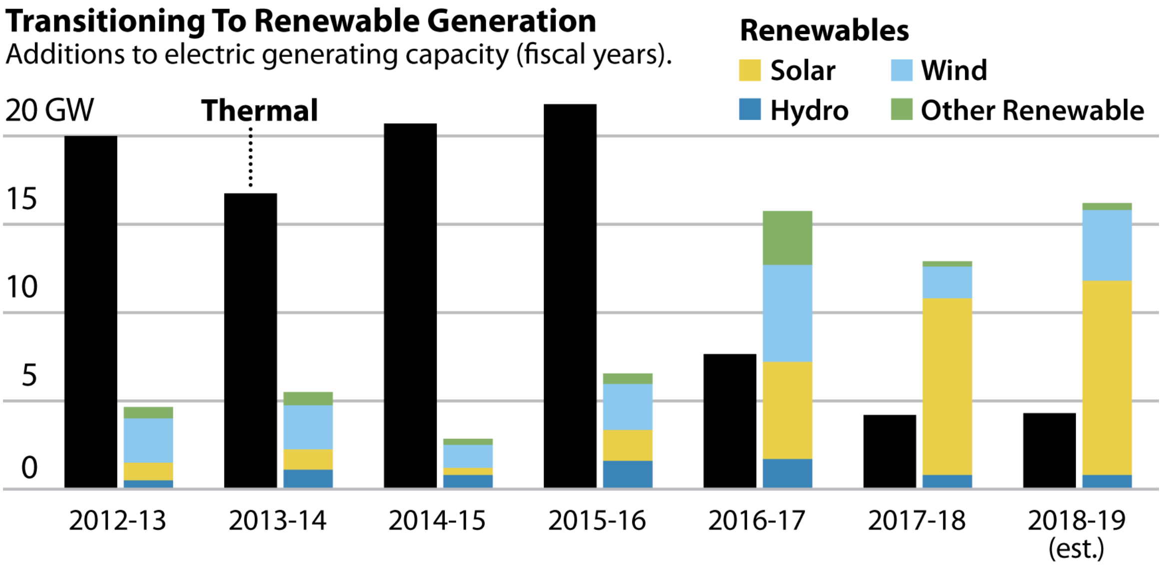
# Chapter 1: Introduction

The Indian electricity sector is undergoing a rapid transition as the share of renewable energy (especially solar and wind) grows while conventional technology (especially coal and natural gas) diminishes. Figure 1 illustrates the dramatic decline in new thermal power plants and the significant increase in new renewable generation capacity since 2012. Today, solar and wind account for more than 80 GW out of a total installed capacity of ~350 GW, and renewables account for approximately 10% of electricity generated.[1] Not only are coal capacity additions decreasing dramatically,[2] but the utilization factors of those plants — the ratio of energy produced for a specified period to the maximum it could have produced — is also decreasing (see Figure 2).[3]

**Figure 1. Annual capacity additions in India (GW)**



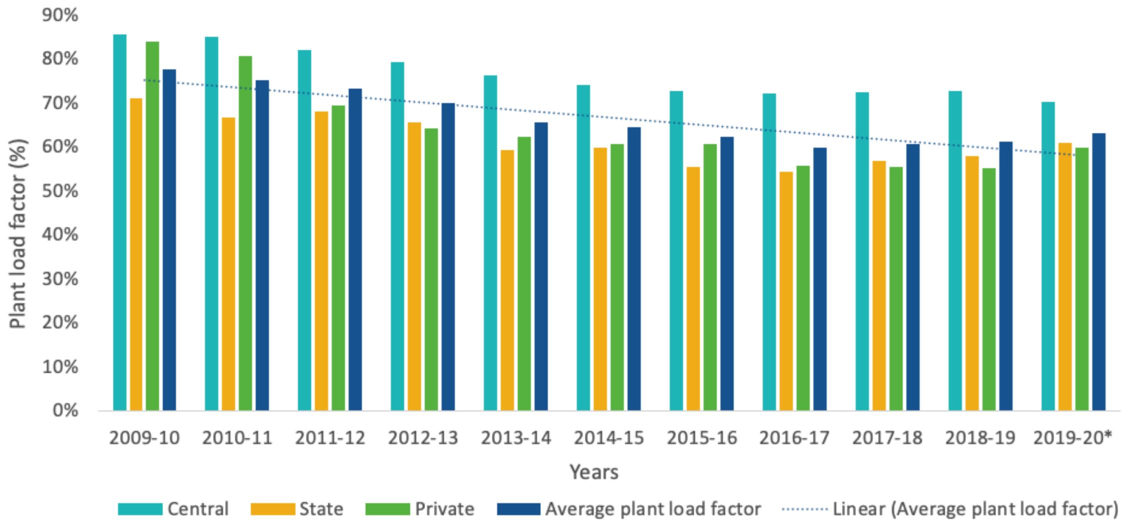

Source: Nicholas, S. (2018). *Something short of an 'amazing opportunity' for U.S. coal.* Used by permission from the Institute for Energy Economics and Financial Analysis.

1 Central Electricity Regulatory Authority. (2019, May). *Executive Summary on Power Sector*. (File No.CEA-CH-14-11/4/2018-Coordination Division). Ministry of Power, Government of India. http://www.cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-05.pdf

2 Nicholas, S. (2018, 5 July). *Something short of an 'amazing opportunity' for U.S. coal*. Institute for Energy Economics and Financial Analysis. http://ieefa.org/ieefa-india-something-short-of-an-amazing-opportunity-for-u-s-coal/

3 Ministry of Power. (2019). *Power sector at a Glance*. Government of India. https://powermin.nic.in/en/content/power-sector-glance-all-india

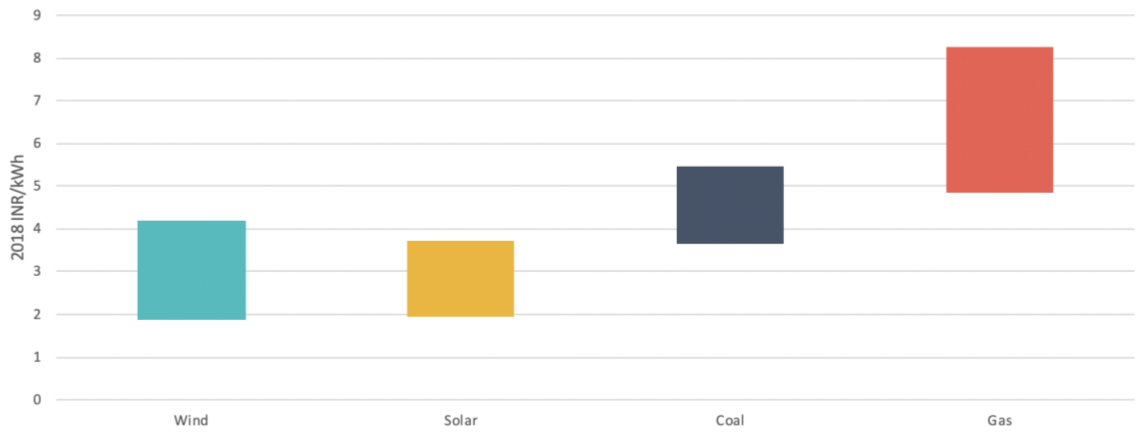
**Figure 2. Plant load factors of thermal generation in India**




*Up to May 2019 (Provisional)

Because of climate change concerns, the government of India initiated this transition over a decade ago with the announcement of the National Action Plan on Climate Change and the National Solar Mission. These plans were implemented through various policy mechanisms, including renewable portfolio obligations, feed-in-tariffs and subsidies in various forms (e.g., viability gap funding, accelerated depreciation, generation-based incentives). Within the last three years, though, the primary rationale for increasing interest in renewable energy is its cheaper cost relative to the cost of coal generation (see Figure 3 for the range of levelised costs of electricity of wind, solar, coal and gas).[4] India also has significant untapped renewable energy potential (Figure 4).[5]

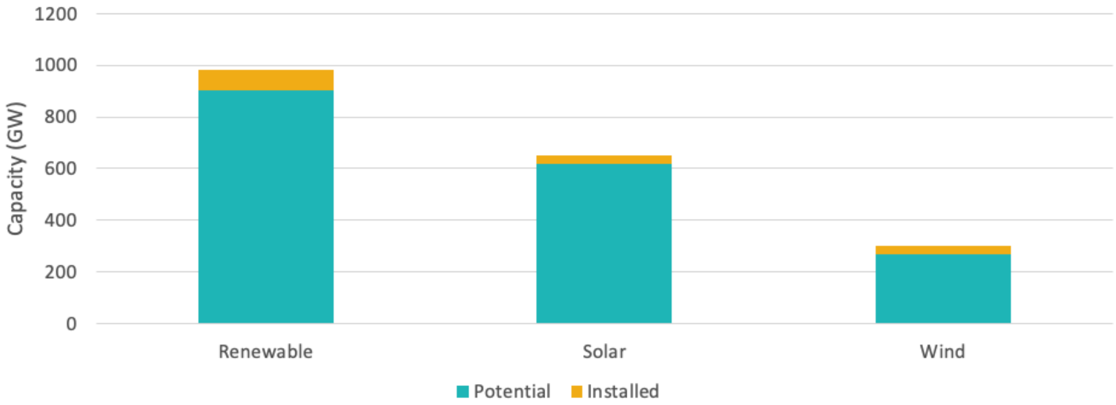
**Figure 3. Levelised cost of wind and solar are lower than coal and gas in India**




4 Jain, A. (2018). *Indian coal power faces long-term headwinds*. Powering Past Coal Alliance. https://poweringpastcoal.org/insights/energy-security/indian-coal-power-faces-long-term-headwinds

5 Central Statistics Office. (2018). *Energy statistics*. Ministry of Statistics and Programme Implementation, Government of India. http://mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2018.pdf

**Figure 4. Untapped renewable energy potential in India**




India is experiencing an energy transition driven by these economic factors, technological changes and policy interventions. The direct implications of the transition on power sector generators, coal-mining companies and Indian Railways are well studied and documented.[6] This study builds on the existing body of research and adds a new dimension — the indirect implications of the energy transition for the nation as a whole and individual states. Our objective is to illustrate the trade-offs that policymakers will need to confront to ensure that the energy transition minimizes negative impacts while preserving the positive impacts.

With the help of a new analytical platform — the E3-India[7] modelling framework — we present a snapshot of the indirect implications of India's energy transition in the year 2030 by comparing a low- and high-renewables energy generation mix. We assess the similarities and differences in these two trajectories rather than comparing the most probable (or sought-after) future with the present. The technoeconomic analysis of the two scenarios — that is, ensuring that the grid is in balance at all instants in a least-cost way — is not a part of this study. Instead, we rely on recent literature where the appropriate technoeconomic analysis has been conducted to form our two scenarios. The Energy Transition Commission's 2018 analysis[8] forms our low-renewables scenario and the Central Electricity Authority's (CEA) 2018 *National Electricity Plan* forms our high-renewables scenario.[9] Using this research as a baseline, we present a comprehensive picture of the interlinkages among key institutions and the potential financial implications of the energy transition.

Using the E3-India modeling framework, we establish that:

- Higher renewable energy in the energy mix leads to cheaper electricity, which in turn results in higher electricity demand across all states.

6 Tongia, R., & Gross, S. (2019). *Coal in India: Adjusting to transition*. Brookings India. https://www.brookings.edu/wp-content/uploads/2019/03/Tongia_and_Gross_2019_Coal_In_India_Adjusting_To_Transition.pdf

7 Details of the initiative and model download is available at URL: https://www.e3indiamodel.com/

8 Pachouri, R., Spencer, T., & Renjith, G. (2018). *Exploring electricity: Supply-mix scenarios to 2030*. The Energy and Resources Institute (TERI) and Energy Transitions Commission. https://www.teriin.org/sites/default/files/2019-02/Exploring%20Electricity%20Supply-Mix%20Scenarios%20to%202030.pdf

9 Central Electricity Authority. (2018). *National Electricity Plan (Volume 1): Generation*. Ministry of Power, Government of India. http://www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf

- Cheaper electricity in the high-renewables scenario leads to higher real disposable income culminating in higher consumer spending across all states, rural and urban areas and income quintiles.
- Cheaper electricity also leads to a shift away from subsidized fossil-fuel use (kerosene and LPG) in the household energy mix to a higher use of electricity.
- Overall GDP and employment are higher in the high-renewables scenario relative to the low-renewables scenario.
- Sectoral impacts are diverse with consumption decreasing in specific sectors like manufactured fuel due to fuel substitution in multiple states.

The study is structured as follows. Chapter 2 provides an overview of the studies that serve as inputs to our analysis. In Chapter 3, we present a comprehensive picture of the relevant institutions likely to be affected by the energy transition and their interlinkages. Our focus is on comprehensiveness, while identifying areas for further research. Chapter 4 presents a first-of-its-kind analysis of the economy- and society-wide implications of the energy transition using a new analytical platform: E3-India.[10] We encourage policymakers and stakeholders to use the E3-India model to develop their own scenarios and analyses. Finally, Chapter 5 highlights the probable trade-offs that policymakers will confront. In most transitions, there are winners and losers. In successful transitions, the losers at least maintain their status, if not improve their situation, through targeted policy interventions. In this chapter, we present a list of the major trade-offs that will have to be addressed by policymakers and stakeholders.

10 The E3-India model is available for free and is transparently documented, rigorously tested and relatively easy to use. Visit www.e3indiamodel.com to learn more and download the model.

# Chapter 2: Transition to what?

India's energy transition can take a wide array of trajectories. This study illustrates the inherent trade-offs that must be confronted under the different plausible trajectories of India's power sector. The study neither advocates for a specific trajectory nor comments on the trajectories presented in the literature. The key focus is to add critical insights on the distributional impacts of transition trajectories across Indian states with respect to key economic parameters like GDP, employment, income and changes in consumption profiles.

As an expanding economy, electricity demand is growing in India.[11] The 19th Electric Power Survey projects an average compound annual growth rate of 4.4% along with a projected ex bus[12] electricity requirement of 2,325 billion kWh by 2030 as compared to 1,048 billion kWh today.[13] A series of recent studies present different trajectories of India's generation mix in the medium (2030) to long term (2050), focusing on the technoeconomic aspects, such as balancing the grid at every instant of time. Further, these studies focus on the trajectory of India's national level energy mix with no insights about state-specific energy mixes. The only comprehensive state-level analysis of probable installed capacities of wind and solar by 2022 is available from the National Renewable Energy Laboratory's India renewable integration study.

The long-term energy supply and transition trends simulated by two different modelling exercises — Bloomberg NEF's *New Energy Outlook*[14] and the International Renewable Energy Agency's (IRENA) *Global Energy Transformation*[15] — consider renewable energy accounting for a 75% and 98% share in the Indian electricity mix by 2050, respectively. The IRENA study further estimates the overall impact on GDP (-0.4%) and employment (+0.2 %) by 2050 using an integrated macroeconometric framework.

The projections of coal in the energy mix by 2030 show a large deviation across studies. Some studies indicate a status quo of 77-75% coal in the energy mix (see, for example, the India Energy Security Scenarios[16] and the Institute of Energy Economics, Japan[17]). More recent studies incorporating incremental renewable additions project a range of 50-61% coal in the generation mix in the medium

11 The Indian economy is expected to grow at an average rate of 6.5% per annum by 2040. International Energy Agency. (2018). *World energy outlook 2018*. https://www.iea.org/weo2018/

12 Installed capacity minus auxiliary consumption.

13 Central Electricity Authority. (2019). *Draft report on optimal generation capacity mix for 2019-30*. Ministry of Power, Government of India. http://cea.nic.in/reports/others/planning/irp/Optimal_generation_mix_report.pdf

14 Henbest, S., Kimmel, M., Giannakopoulou, E., Kang, D., Zindler, E., Gandolfo, A., Brandily, T., Berrymand, I., Callens, J., Chatterton, R., Hostert, D., Turner, A., Cuming, V., Sprinz, J., Goldie-Scot, L., Chase, J., Harries, T., Lu, S., Vickers, B., & Sutter, L. (2018). *New energy outlook 2019*. BloombergNEF. https://about.bnef.com/new-energy-outlook/

15 International Renewable Energy Agency. (2018). *Global energy transformation: Roadmap to 2050*. IRENA. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf

16 National Institution for Transforming India (NITI) Aayog. (2015). *India energy security scenarios, 2047 Version 2.0.* Government of India. https://participatorydemocracyin.files.wordpress.com/2015/06/call_for_evidence_15-06.pdf

17 IEE Japan. (2018). *IEEJ outlook 2018: Prospects and challenges until 2050*. Institute of Energy Economics. https://eneken.ieej.or.jp/data/7748.pdf

term (see, for example, the Energy Transition Commission,[18] the International Energy Agency's *World Energy Outlook*[19] and CEA's *National Electricity Plan*[20]).

India's policy targets provide directional guidance for the pace and scale of the transition. Projections for additional coal-fired capacity also see a large deviation in many recent studies. For example, the government of India bases projections on the need for an additional 48 GW by 2026-2027.[21] However, earlier studies have indicated an additional 81-110 GW is needed between 2015 and 2020.[22]

The current study complements the existing body of literature by adding an explicit socioeconomic context to the transition story both at the national level and with much greater granularity at the state level. We evaluate the direct and indirect impacts in 2030 of two trajectories: a high-renewables (427 GW added to the electricity mix) scenario and a low-renewables (269 GW of capacity added) scenario. We assume the addition of comparable coal capacities (72-76 GW) under both scenarios by 2030. The objective of the study is to assess similarities and differences between these two distinct transition trajectories rather than comparing the most probable or sought-after future with the present.

## Constructing the transition scenarios

We developed the scenario inputs based on the following three topical studies. This allows us to compare results and provide consistency with existing analysis.

- ***Exploring Electricity Supply-Mix Scenarios to 2030*, The Energy and Resources Institute and Energy Transition Commission (ETC):** The ETC scenarios assume GDP growth of 6.8% until 2030 with grid demand reaching 2,040 TWh by 2030. These are similar to projections in the 19th Electric Power Survey of the CEA. The study analyzed the following three scenarios:
    - **Current trajectory scenario.** The scenario assumes lower growth in coal capacity additions through 2022 due to prevalent issues of nonperforming assets in the power sector along with current renewable energy policy targets missed by a moderate margin. Post 2022, aggressive addition of coal capacity is assumed (65 GW by 2030). The coal plant load factors increase from 59% in 2022 to 73% by 2030. Our study uses this scenario as the low-renewables scenario.
    - **Current policy scenario.** This scenario corresponds to the government's policy target of 175 GW of renewables by 2022 followed by National Electricity Plan projections. The scenario assumes a net coal capacity addition of 41 GW by 2030.
    - **High-renewables scenario.** No coal capacity addition is assumed after 2022, along with higher growth rate of solar PV and wind post 2022. The total coal capacity reduces to 6 GW by 2030 under this scenario.

18 See footnote 7.

19 International Energy Agency, 2018.

20 Pachouri et al., 2018.

21 Central Electricity Authority, 2018.

22 Sehgal, A., & Tongia, R. (2016). *Coal requirement in 2020: A bottom-up analysis*. Brookings India. https://www.brookings.edu/wp-content/uploads/2016/09/2016_08_16_coal_future_2020_asrt.pdf

- ***Draft Report on Optimal Generation Capacity Mix for 2029-30*, CEA, Ministry of Power:** This study uses the computer-based ORDENA model to determine the optimal generation mix to meet the peak electricity demand and electrical energy requirement for the year 2029-2030 with the objective of minimizing the total system cost subject to various constraints. The study considers an aggressive increase in solar (300 GW) and a somewhat constrained wind increase to 140 GW. The study assumes coal capacity of 267 GW operating at a 55% plant load factor and includes battery storage capacity of 36 GW for flexibility needs. Our study uses similar assumptions for capacity mix to form the high-renewables scenario.[23]

- *Greening the Grid Report: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid,* National Renewable Energy Laboratory, Posoco and Berkeley Lab for Ministry of Power: Both the scenarios used to inform our study only provide results at the national level. The state-level distribution of electricity generation mix is extrapolated from this study where state-level distribution was provided for the year 2022. This is a crucial determinant of state-level indirect impacts because GDP and employment are dependent on investments made in the states. This study uses an extensive production cost model to allocate solar and wind capacities across states. The grid is balanced at the regional level with 15-minute interval generation data. The coal capacities are simulated to operate at 55% plant load factor. We are seeking state-level data from both the ETC and CEA teams, if available, to ensure accurate capacity mixes at the state level.

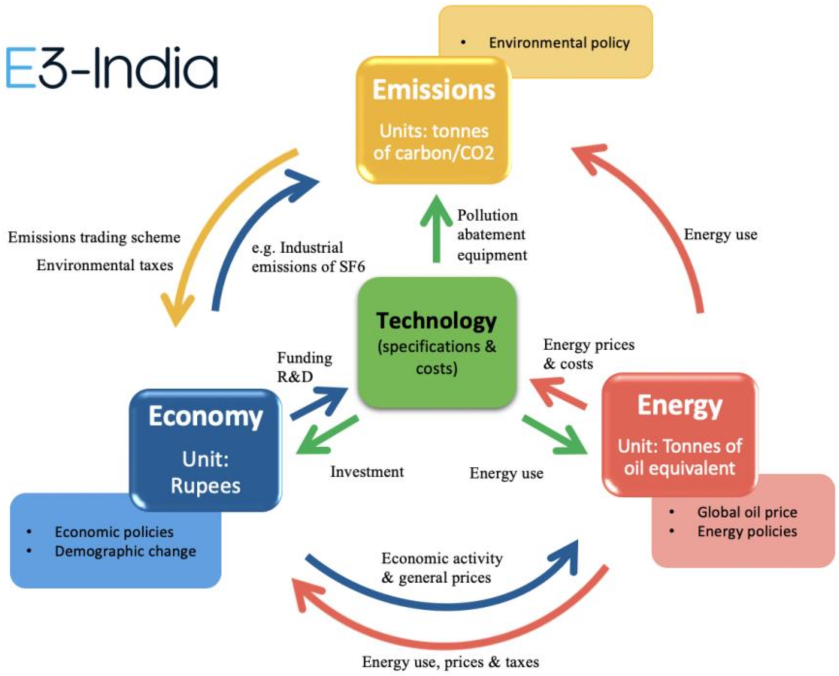
Based on these scenarios, we developed an exogenous input for capacity addition of various generation technologies to use with the E3-India model: a state-level integrated energy-economy model that captures two-way linkages and feedbacks among India's state economies, energy systems and emissions.[24] The model also features a unique Future Technology Transfer (FTT) model to evaluate transitions in the power sector (Figure 5).[25] The details of the modelling framework and model specifications are delineated in Annexure 4.

[23] The high-renewables scenario in our study does not include battery storage, which the CEA analysis does; however, the requirement for increased flexibility is modelled through increased oil and gas generation as backåup technology to manage demand.

[24] The analysis was performed using an advanced version of E3-India, which is expected to be available in the public domain by the end of August 2019; however, a beta version of the model and the reference document are available on request (please contact: sjoshi@raponline.org).

[25] Pollitt, H. (2017). *Introduction to the E3-India macroeconomic model.* IORA Conference. https://www.e3indiamodel.com/wp-content/uploads/2018/04/pollitt-intro-e3-india-macroeconomic-model-IORA.pdf

**Figure 5. Overview of the E-3 India framework**




Source: Pollit, H. (2017). *Introduction to the E3-India macroeconomic model*.

Figures 6 and 7 provide an overview of the capacity additions and generation mix simulated through 2030 for both the low- and high-renewables scenarios. Utilizing the E-3 India model, we provide insights on the direct and indirect impacts of incremental renewable capacity addition in 14 key states: Andhra Pradesh and Telangana, Chhattisgarh, Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal and Delhi. In 2018, these states accounted for more than 89% of coal, 97.2% of wind and 93.2% of solar capacities installed in India. The details of solar and wind capacity additions modelled to 2030 across Indian states are presented in Annexure 3.

**Figure 6. Assumed installed capacity (GW)**

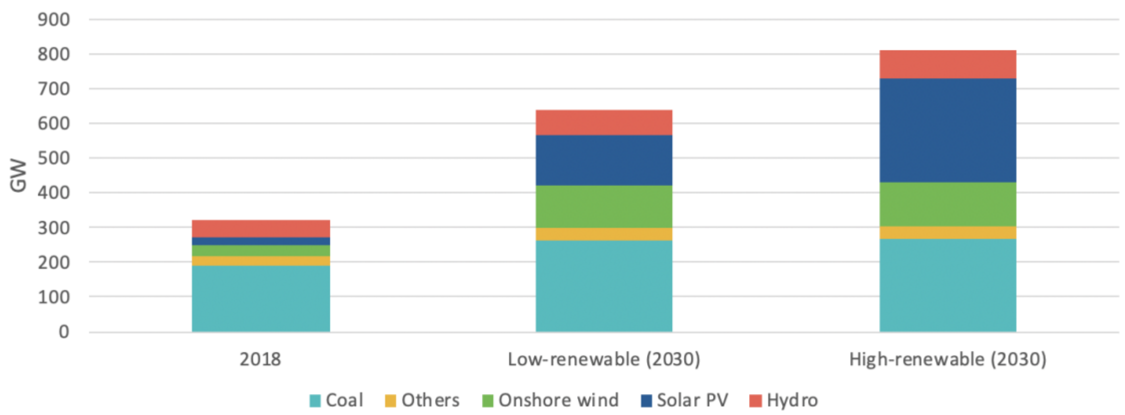
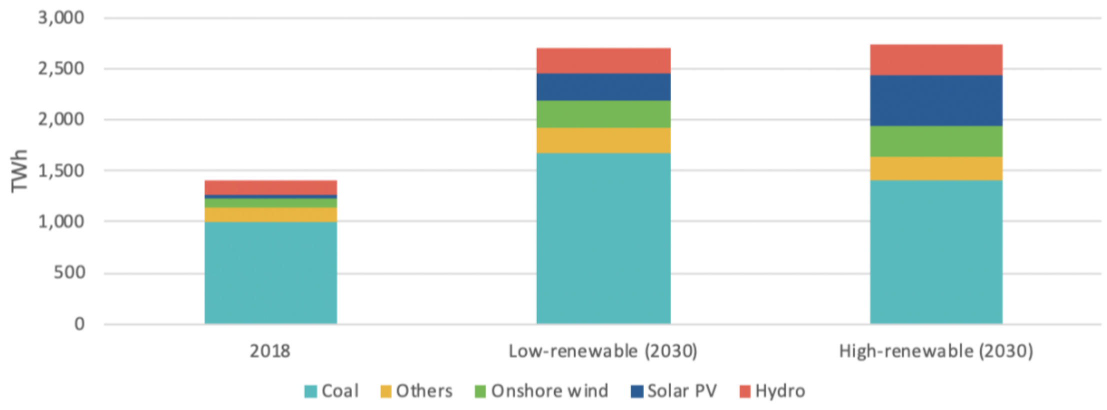


**Figure 7. Assumed generation mix (TWh)**



# Chapter 3: Who is affected by the energy transition?

The past leads to the present and influences the future; however, the future is not a mirror of the past. Stakeholders who benefitted in India's electricity growth story of yesterday may find themselves on losing ground as the rules of the game change. A transition to a cleaner and sustainable energy future may therefore not bode well for these stakeholders — the incumbents in the electricity sector value chain. The new business environment may lead to decreasing economic competitiveness unless they recognize the transition that is underway and adopt strategies for sustenance and growth in the new disrupted environment.

However, these incumbents may resist structural changes that they consider detrimental to their business operations, even though signs of these structural changes have been around for some time. Any transition study is thus a study of the capital and communities involved and warrants a thorough analysis of (a) who may be responsible for pushbacks, (b) the flow and volume of socioeconomic linkage that these incumbents dominate and (c) the level of impact the transition may have on these incumbents. In this chapter, we examine these questions.

As described in the previous chapter, the transition trajectories are such that the role of coal is not completely diminished by 2030. In fact, it expands in both scenarios as compared to today, although the two scenarios have significant differences. In the high-renewables scenario, the absolute usage of coal is substantially smaller than in the low-renewables scenario. Consequently, the institutions looked at in this chapter will need to assess the risks they face under these two scenarios from the vantage point of what decisions they may need to make that would allow them to manage risks better, for example, no-regrets decisions, high-risk decisions and so on.

## 3.a. Understanding the stakeholders

The electricity sector value chain is a primary starting point to identify key stakeholders in the energy transition. That means all companies and agencies involved in the business of coal mining; transportation; power generation, transmission and distribution; and allied activities — such as coal beneficiation, manufacture of power plant equipment, engineering procurement and construction, fly ash disposal and supply of emissions control technologies.

### Coal mining and production

India is the second largest producer of coal in the world, after China. Close to 80% of its coal mining is concentrated in the states of Odisha, Jharkhand, Chhattisgarh and Madhya Pradesh.

Domestic coal production was 689 million tonnes (MT) in FY18 and is expected to reach 795 MT in FY20.[26] Of this, Coal India Limited produces around 83%, followed by 9% from Singareni Collieries Company Limited and 8% from captive mines owned by private coal companies. In addition, about

26 Motilal Oswal. (2018, December). *Utilities*. Sector update. https://www.motilaloswal.com/site/rreports/636812386917488508.pdf

200 MT of coal is imported every year, coming primarily from Indonesia (almost 50%), South Africa, Australia, the United States and Russia.[27]

Domestic production of coal has increased at a compound annual growth rate of 4.80% over FY03-FY18, while coal imports have grown at a rate of 13.06% in the same period. Technical complexity, high development costs, delays and litigation in private coal mine development in India are the primary reasons for the increasing share of imported coal.

Coal consumption for power generation has increased at a rate of 4.44% over the last five-year period.[28] See Annexure 1 for yearly details of domestic production and imports of coal. At an average realisation (estimated sale price) of domestic coal at 2,440 INR/tonne[29] and imported coal at 5,000 INR/tonne, the total market size of India's coal industry is 2.7 INR trillion. The domestic industry accounts for 60% of the market.

Coal mining and production is one of the eight core industries that together comprise 40.27% of India's Index of Industrial Production (IIP). It carries a weight of 10.33% in the Index of Eight Core Industries, published monthly by the Ministry of Commerce and Industry.[30]

Coal India Limited (CIL), a Maharatna company,[31] came into existence as a consequence of the central government nationalizing the coal industry.[32] As of 30 May 2019, the government of India holds 71% of total equity share capital and is the largest shareholder of the company. In addition, the government holds 49% in Singareni Collieries Company Limited (SCCL), which operates 48 mines with a total production of 62 MT per year, and 82% in Neyveli Lignite Corporation (NLC), which operates four lignite mines with a total production of 30 MT per year.

Together, these companies employ 500,000 full-time employees, with 304,387 working at CIL, 54,043 at SCCL and 14,446 at NLC. The lion's share of employment is, however, in the largely unorganized sector supporting coal mining. Although estimates vary widely, one study estimates that this sector employs close to 6 million people.[33]

CIL acknowledges the rise of competition from renewable energy. In its *Coal Vision 2030* report, a stakeholders' consultation, the company stated that 'in the case of coal industry in India, trends portend that in the long run the demand is likely to decrease substantially. However, the inflexion point is still unknown. With the increasing threat of climate change impacting humanity (irrespective of the U.S. position) and the global funding focus on renewables, it is a matter of time when alternate

27 Argus Media Group. (2019, March). *India, China and Southeast Asia drive global thermal coal trade higher*. https://www.argusmedia.com/-/media/Files/white-papers/india-china-and-southeast-asia-drive-global-thermal-coal-trade-higher.ashx

28 Central Electricity Regulatory Authority, 2019.

29 Average cost of production is about 1,000 INR/tonne. Taxes, duties and levies account for up to 25%, and freight accounts for up to 34%. See Coal India Limited. (n.d.). *Coal vision 2030: Stakeholders' consultation.* https://www.coalindia.in/DesktopModules/DocumentList/documents/Coal_Vision_2030_document_for_Coal_Sector_Stakeholders_Consultation_27012018.pdf

30 Ministry of Commerce and Industry. (2019). *Index of eight core industries (Base: 2011-12=100) April, 2019* [Press release]. Government of India. http://www.pib.nic.in/Pressreleaseshare.aspx?PRID=1572939

31 Department of Public Enterprises. (2018, April). *Maharatna, Navratna and Miniratnas CPSEs*. http://www.pib.nic.in/Pressreleaseshare.aspx?PRID=1572939

32 For more on CIL's history and operations, see Coal India Limited, n.d.

33 Mukherjee, S. (2017, 10 November). Unorganised sector in coal mines of India. *International Journal of Engineering, Economics and Management, 2*(1). http://ijeem.org/Papers/May%20Issue/Unorganised%20Sector%20in%20Coal%20Mines%20of%20India.pdf. See also Aney, S. (2017, 10 November). *Coal and the future of India: Workers' Mahapadav*. NewsClick. https://www.newsclick.in/coal-and-future-india-workers-mahapadav

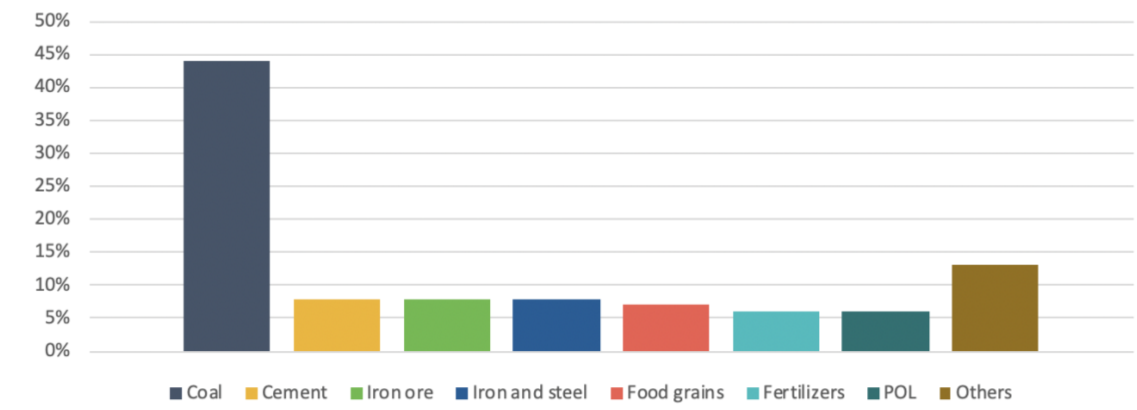
clean energy would displace coal. Standing in the midst of a change, it is very difficult for anyone to imagine its scale and often most people remain in a state of denial until the change is upon them'.[34]

Recognizing the need for change, CIL in its annual report for FY18 also notes that '[i]n the light of Paris Protocol and consequent upon changes in world energy sector scenario, CIL is looking forward to diversify its operations towards Renewable energy like Solar Power and Clean Energy sources like CMM, CBM, CTL, UCG etc. following the directives of GoI'.[35]

## Coal transportation

Indian Railways has been the primary mode for coal transportation — both coking as well as noncoking coal — due to economic and physical limitations of other transportation options. Coal is the biggest bulk commodity for Indian Railways in terms of freight share as well as earnings share (Figure 8). Coal accounts for about half of Indian Railways' freight traffic, 40% of net tonne kilometre of transport and almost half of total freight revenue.[36]

**Figure 8. Commodity share in Indian Railways freight revenue**




Indian Railways delivers roughly half of the coal required by power plants, while the balance — about 300 MT — is transported by trucks on highways.[37] With coal mining primarily concentrated in the eastern parts of the country (see Table 1) and power generators in the west and southern regions (where the demand is concentrated, see Table 2), coal transportation is both a costly and time-consuming affair for power plants.

34 Coal India Limited, n.d.

35 Coal India Limited. (2018). *Annual report & accounts: 2017-2018*. Deluxe English. https://www.coalindia.in/DesktopModules/DocumentList/documents/Annual%20Report201718.pdf

36 Indian Railways transported 546 MT of coal in FY15, 552 MT in FY16 and 533 MT in FY17, with an earnings share (from coal) in total freight revenue of 45.90%, 46.15% and 44.33%, respectively. See National Council of Applied Economic Research (NCAER). (2016). *Factors impacting railway freight traffic in India*. (Report No. 2016-02-1). http://www.ncaer.org/publication_details.php?pID=264; and Indian Railways. (2017). *Indian Railways annual report & accounts: 2016-17*. http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/IRSP_2016-17/Facts_Figure/Indian%20Railways%20Annual%20Report_Accounts%20English%202016-17.pdf

37 Concerns over reliability and quality of supply have forced power plants to try alternatives to Indian Railways, especially in times of need, such as during late monsoon months of August and September. In fact, the Ministry of Power and Indian Railways require all power plants within 20 kms of a coal mine to be supplied by road alone.

**Table 1. Coal-producing states by Coal India subsidiary**

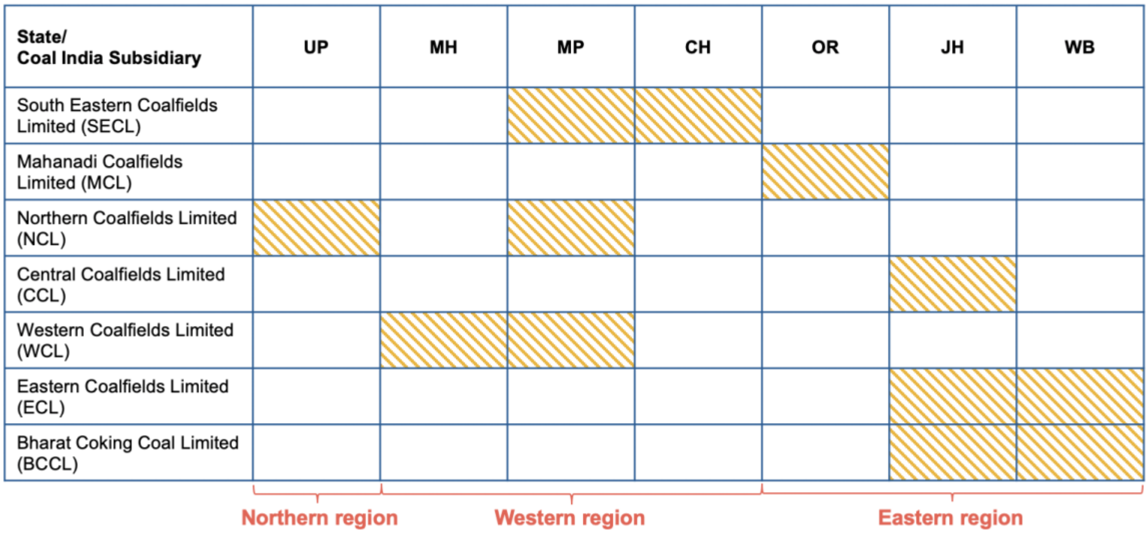


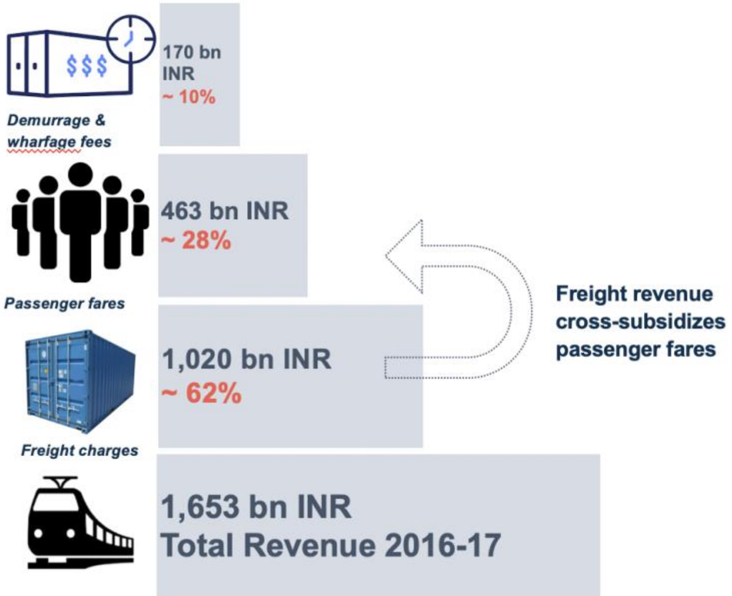

**Table 2. Regional coal consumption**

| Region | Coal-based power plant installed capacity (MW) | FY19 coal consumption (MT) |
|---|---|---|
| Western Region | 82,371 | 285.03 |
| Northern Region | 41,604 | 143.41 |
| Southern Region | 40,912 | 134.88 |
| Eastern Region | 32,275 | 115.22 |
| North-East Region | 750 | 1.88 |
| **Total** | **1,978,912** | **680.42** |

CIL and Indian Railways are heavily dependent on each other for their financial success, so much so that the Member (Traffic Transportation) of the Railway Board is a permanent invitee to all management committee meetings of CIL. Indian Railways' freight revenue — half of which is accounted for by coal — helps cross-subsidize passenger fares (see Figure 9).[38] Any reduction in coal transportation is, thus, a major cause of concern for Indian Railways.

According to Indian Railways' *Year Book 2017-18*, total coal transported by rail has gradually decreased over the last five years, from 69.34% in FY14 to 62.75% in FY18 (projected).[39] Brookings India (2018) predicts that the rate of coal transportation may continue to decline due to relatively slow growth of electricity demand, high renewable energy capacity additions (near load centers, which will further reduce the distance of coal transportation) and improved power plant efficiencies.

**Figure 9. Understanding Indian Railways revenue sources**




An important cause of worry for power generators is the quality of coal and theft during transportation, especially via trucks. This dark side of the unorganized sector's role in coal mining and transportation has been noted by some studies[40] and has even been a favorite topic for several Bollywood movies. The number of people working in this unorganized sector is not known. Trucking is a highly fragmented industry in India, and often the transport companies are local players with an unidentified number of people employed as contract employees. A decrease in coal usage could impact employment in this unorganized sector.

Indian Railways has admitted that it needs to scout for new freight revenue opportunities to hedge risks from overdependence on select commodities.[41] It also has explored other nonfare revenue

38 Kamboj, P., & Tongia, R. (2018). *Indian Railways and coal: An unsustainable interdependency*. Brookings India. https://www.brookings.edu/research/indian-railways-and-coal/

39 Ministry of Railways. (2018). *Year-book 2017-18.* Government of India. http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/pdf_annual_report/Railway%20Year%20Book_2017_18.pdf

40 Daniel, F. J., & Williams, M. (2013). *Special report: 'Coal mafia' stokes India's power crisis.* Reuters. https://www.reuters.com/article/us-india-coal-specialreport/special-report-coal-mafia-stokes-indias-power-crisis-idUSBRE94D00520130514

41 Ministry of Railways. (2016). *Ministry of Railways organizes an interactive seminar with major industries and stakeholders of Indian Railways freight business* [Press release]. Government of India. http://pib.nic.in/newsite/PrintRelease.aspx?relid=146447

resources, including station redevelopment, monetization of land along tracks, advertising and revenue from manufacturing of coaches and rakes for the international market.[42]

Electrification and decarbonization have been key agenda items for Indian Railways in the recent past. It has invested in 11 MW of solar capacity and 37 MW of wind power capacity for its own use and plans to invest in 1,000 MW of solar and 130 MW of wind projects by 2022.[43]

## Coal-based power generation

Electricity generation is also part of the eight core industries in India's Index of Industrial Production and carries a weight of 20% in the Index of Eight Core Industries. As of March 2019, India has 198 GW of coal-based power plants, of which 29% are central sector plants, 32% are state sector plants and the rest (39%) are private sector owned.[44] Central, state and private sector power plants operated at an average plant load factor of 61%, 56% and 43%, respectively, in FY19. Table 3 provides a list of the top 10 power plants ranked according to their estimated coal consumption[45] in FY19.[46]

**Table 3. Top coal-consuming power plants and emissions**

| Plant name | Ownership type | Ownership | Capacity (MW) | Coal consumption FY19 (MT) | CO2 emissions FY19 (metric tonnes CO2) |
|---|---|---|---|---|---|
| Vindhyachal STPS | Central | NTPC | 4,760 | 24.99 | 36.41 |
| Sasan UMTPP | Private | SPL | 3,960 | 21.89 | 31.89 |
| Mundra UMTPP | Private | CGPL | 4,000 | 17.86 | 26.02 |
| Mundra TPS | Private | APL | 4,620 | 15.92 | 23.19 |
| Sipat STPS | Central | NTPC | 2,980 | 15.92 | 23.19 |
| Rihand STPS | Central | NTPC | 3,000 | 15.10 | 22.01 |
| Tirora TPS | Private | APL | 3,300 | 14.42 | 21.02 |
| Talcher STPS | Central | NTPC | 3,000 | 14.14 | 20.61 |
| Anpara TPS | State | UPRVUNL | 2,630 | 13.39 | 19.51 |
| Korba STPS | Central | NTPC | 2,600 | 13.37 | 19.48 |
| **Total** | | | **34,850** | **152.86** | **243.33** |

There are no coal power plants in the states of Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Goa, Kerala, Sikkim, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and the union territories of Puducherry and Andaman and Nicobar Islands. Although some states consume a relatively small amount of power, they have significant installed coal-fired capacity (Figure 10). For

42 Ministry of Railways. (2016). *Railways to increase revenue through non-fare sources* [Press release]. Government of India. http://pib.nic.in/newsite/PrintRelease.aspx?relid=136771

43 For more information, see Indian Railways. (n.d.). Indian Railways green energy initiatives. http://www.irgreenri.gov.in

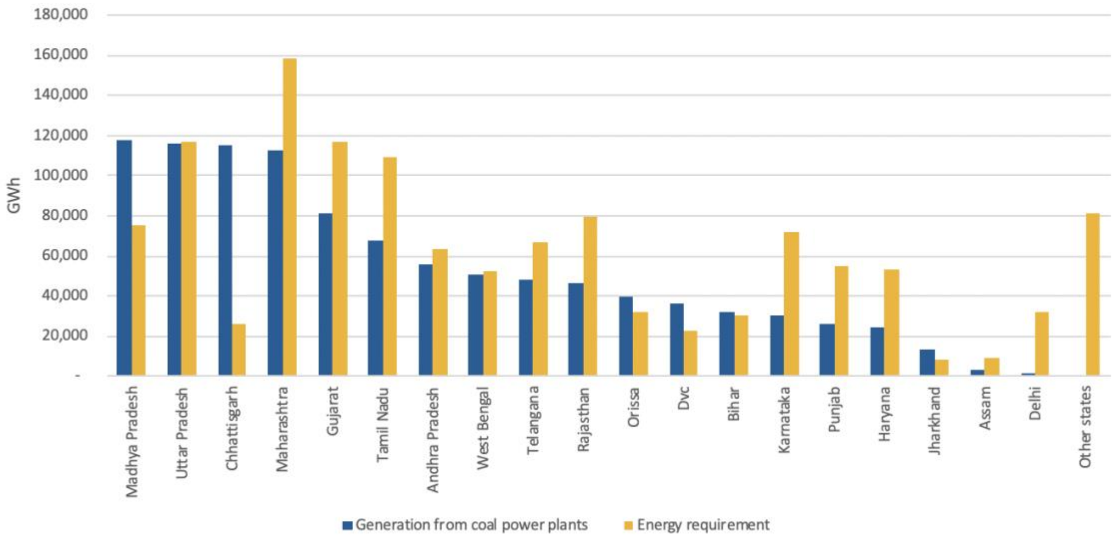
44 Central Electric Authority. (2019). Energywise: Performance status all India: Regionwise. http://www.cea.nic.in/reports/monthly/generation/2019/March/tentative/opm_16.pdf

45 Assuming a gross station heat rate of 2,500 kCal/kWh and a gross calorific value of coal at 3,755 kCal/kg.

46 Details of state-wise installed capacity, coal consumption and carbon dioxide emissions are provided in Annexure II.

these states, including Madhya Pradesh, Chhattisgarh, Odisha and Jharkhand, any change in the procurement portfolio by the importing states poses a significant challenge. These states have witnessed significant investment in new coal-fired plants over the last five-to-10 years, thus exposing the industry to risks of reduced dispatch in future.

**Figure 10. Fiscal year 2019 coal generation and energy requirements by state**




Employee productivity at these power generation companies (gencos) demonstrates a wide variation with the type of ownership. NTPC (National Thermal Power Corporation) employs 19,739 employees, MSPGCL (Maharashtra State Power Generation Company Limited) has 15,000 employees on payroll and Tata Power has only 2,871 employees working across all business segments. Extrapolating from the basis staff strength of NTPC, an approximate 100,000 employees may be working as full-time employees in all gencos put together, with another equal or higher number of employees working as contract workers.

The top five coal-fired generating companies include NTPC, Adani Power, MSPGCL, Tata Power and DVC (Damodar Valley Corporation). Together, they account for 41% of total installed capacity. See Table 4 for an overview of their current capacities, plans for coal expansion and diversification proposals. The plans for diversification demonstrate management's desire to hedge their business risks and protect shareholder value.

**Table 4. Top five generation companies based on coal capacity**

| Genco (coal projects) | Plans for conventional growth | Plans for diversification |
|---|---|---|
| NTPC (39,650 MW) and NTPC JVs (6,270 MW): central genco | Coal-based capacity under construction FY18 13,110 MW. Plans to explore opportunities in international market. A 2x660 MW coal-based project is under construction in Bangladesh. | Renewable project capacity of 928 MW installed. FY18 annual report notes 'adding capacity through RE, to broad base its generation mix to ensure long-term competitiveness, mitigation of fuel risks and promotion of sustainable power development'. |
| Adani Power (10,440 MW): private genco | Plans to increase generation capacity up to 5% of India's total capacity by 2021. | 40 MW solar project commissioned in 2011 in Gujarat. |
| MSPGCL (10,170 MW): state genco | Coal-based capacity under construction 3,230 MW. | Has an installed 130 MW solar project and plans to add another 320 MW and says that it has a 'clear vision for green power for consumers of Maharashtra'. |
| Tata Power (7,178 MW): private genco | None. In fact, the company wants to reduce its fossil-fuel based capacity to 50% of the total portfolio. | FY18 annual report is titled *Renewables to Power Growth* and at several places recognizes the company's vision of becoming a leader in renewable energy. TPC has an installed base of 1,161 MW wind projects and 1,188 MW solar projects. |
| DVC (7,090 MW): central genco | Plans to add 3,580 MW of coal-based capacity as extensions or replacements to older units. | Plans to set up 1,000 MW solar capacity in West Bengal and Jharkhand. |

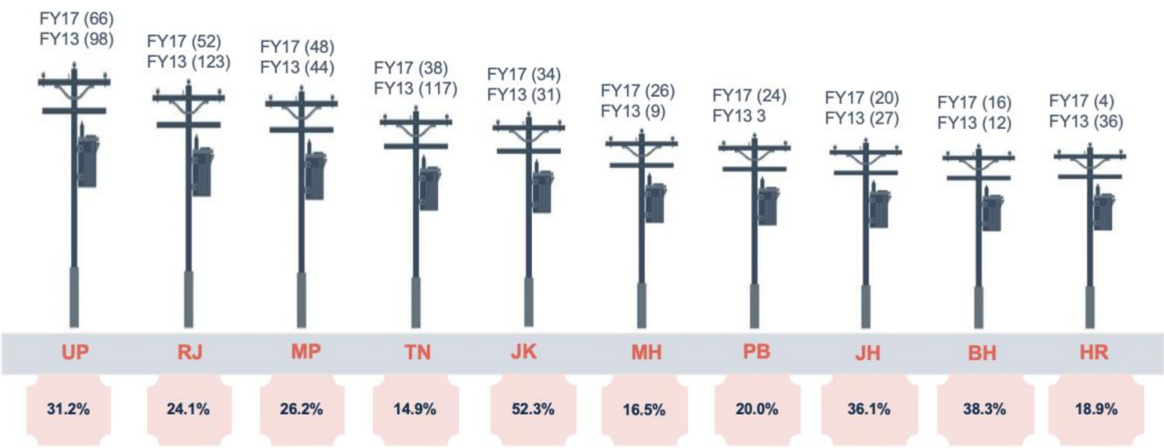
## Power distribution

Distribution utilities (discoms) should optimize power procurement from two interdependent perspectives. The first is to minimize the cost to purchase power (which is approximately 60% of their total annual revenue requirement) and the second is to ensure efficient integration of all resources while balancing demand and supply (to meet their requirements for base load and peak load).

Currently, discoms have a unique advantage since the costs of renewable energy have come down drastically. They have shown willingness to add more renewable sources and cut down on their power procurement from coal-fired power plants. Discoms' financial position is very weak (see Figure 11), and they have accumulated substantial losses over the years. The central government has repeatedly come up with bailout schemes to pull them out of losses, but they continue to face immense fiscal problems and need to explore every single opportunity to cut down on costs and improve operational efficiency.

In that context, uncontracted coal-fired power plants that have high variable costs are at substantial risk of not being dispatched in the medium to long term. Already some discoms have started asking for renegotiations with high-cost plants, and that behaviour may be emulated by others in the near future.

**Figure 11. Discom aggregrated loss (INR billion and percent)**




## Financial institutions

The total outstanding power sector debt of India's scheduled commercial banks is about 5.6 INR trillion.[47] This includes capital expenditure debt financing as well as working capital loans to companies in power generation (including renewables), transmission and distribution. Of this total, approximately 80% is provided by public sector banks and the balance by private banks (see Table 5 for a list of banks with the highest exposure as reported in their annual reports).

**Table 5. Banks exposure to the power sector**

| Bank name | Exposure as of December 2017 (INR bn) | Exposure as of December 2018 (INR bn) |
|---|---|---|
| State Bank of India | 1,674.96 | 1,951.33 |
| Bank of Baroda | 327.04 | 199.96 |
| Union Bank of India | 297.86 | 238.37 |
| Axis Bank | 247.08 | 146.51 |

The power sector has been a cause of severe worry to the banking community, especially in the last few years, with several loans turning into nonperforming assets. This clogging of the banks' balance sheets has led to a slowdown in overall lending.[48] This situation of stressed assets from the power

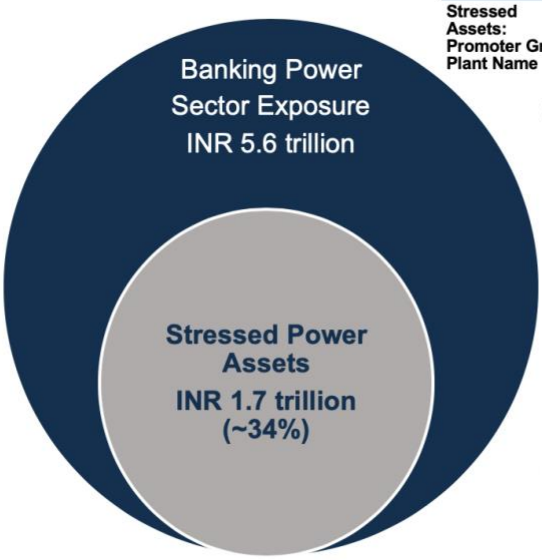
47 HDFC Bank Investment Advisory Group. (2018). *Power sector: Sector report*. https://www.hdfcbank.com/assets/pdf/privatebanking/Power-Sector-Update-September-2018.pdf

48 Money Control. (2018). *Banks will have to 'abort' lending to infrastructure sector, power companies, warns SBI*. https://www.moneycontrol.com/news/business/banks-will-have-to-abort-lending-to-infrastructure-sector-power-companies-warns-sbi-2904781.html

sector — which together owe 1.7 INR trillion (see Figure 12) — has been worsening due to several factors, such as the price of imported coal, unavailability of domestic coal, absence of contracts with discoms, the reneging of operating contracts, lower plant load factors due to higher variable costs, competition from cheaper renewables and also crony capitalism. Discoms that are chronically financially distressed further expand the problem by not paying gencos' invoices for power sale on time. The Ministry of Power's database of payment status to all gencos reports an outstanding debt of 358 INR billion as of 30 April 2019.[49]

This particular risk of stranded fossil-fuel assets is not just specific to India but part of a larger systemic shift in the sector globally.[50] However, given the pace at which new coal-fired plants were added from 2010 to 2017, the problem is especially acute in India, particularly in the states of Chhattisgarh, Jharkhand, Madhya Pradesh and Maharashtra, which witnessed rapid capacity addition.[51] For these states, the economic promise from new power plants did not materialize. Instead, a timely shift in resource allocation (land, capital and skills) to a low-carbon economy would have helped them become leaders in the new landscape.

**Figure 12. Stressed power plants account for one-third of the banking sector's exposure**




| Stressed Assets: Promoter Group, Plant Name | |
|---|---|
| 23% | **Debt > INR 100 bn**: KSK Mahanadi Power, Akaltara; Adani Power Maharashtra, Tirora Ph 1 & 2; Jaypee Power Ventures, Bara |
| 46% | **Debt between INR 50 - 100 bn**: RKM Powergen,Uchinpanda; Lanco, Amarkantak; GMR Chattisgarh Energy, Raikheda; Rattan India, Nasik Ph 1; Lanco, Babandh; DB Power, Baradhra; Jaypee Power Ventures, Nigrie; Coastal Energen, Mutiara; Essar Power, Mahan; Jindal India, Derang; Monnet Power, Malibrahmi; Athena Chattisgarh Power, Singhitarai |
| 17% | **Debt between INR 30 - 50 bn**: SKS Power, Binjkote; Lanco, Vidarbha; GMR Kamlanga Energy, Kamlanga; GVK Industries, Goindwal Saheb; Avantha Power Jhabua, Seoni; Essar Power, Tori; Adani, Korba West, Lanco, Anpara |
| 14% | **Debt < INR 30 bn**: Ind Bharath Energy, Utkal; GMR Energy, EMCO Warora; East Coast Energy, Bahvanpadu; Kanti Bijlee Utpadan Nigam, Muzzafarpur; Adhunik Power, Mahadev Prasad Ph 1; Damodar Valley Corp, Raghunathpur; Jaypee Power Ventures, Bina; Mudhucon, Simhapuri Energy; Vandana Vidyut, Salora; Visa Power, Deveri; KVK Nilachal Power, Nilachal |

## 3.b. Understanding financial linkages

Any transition trajectory will impact stakeholders in varying ways depending upon how and how much they are dependent on the current business environment. There are bound to be losers and winners, in varying degrees and over different trajectories, necessitating different strategies to minimize pain and maximize gain.

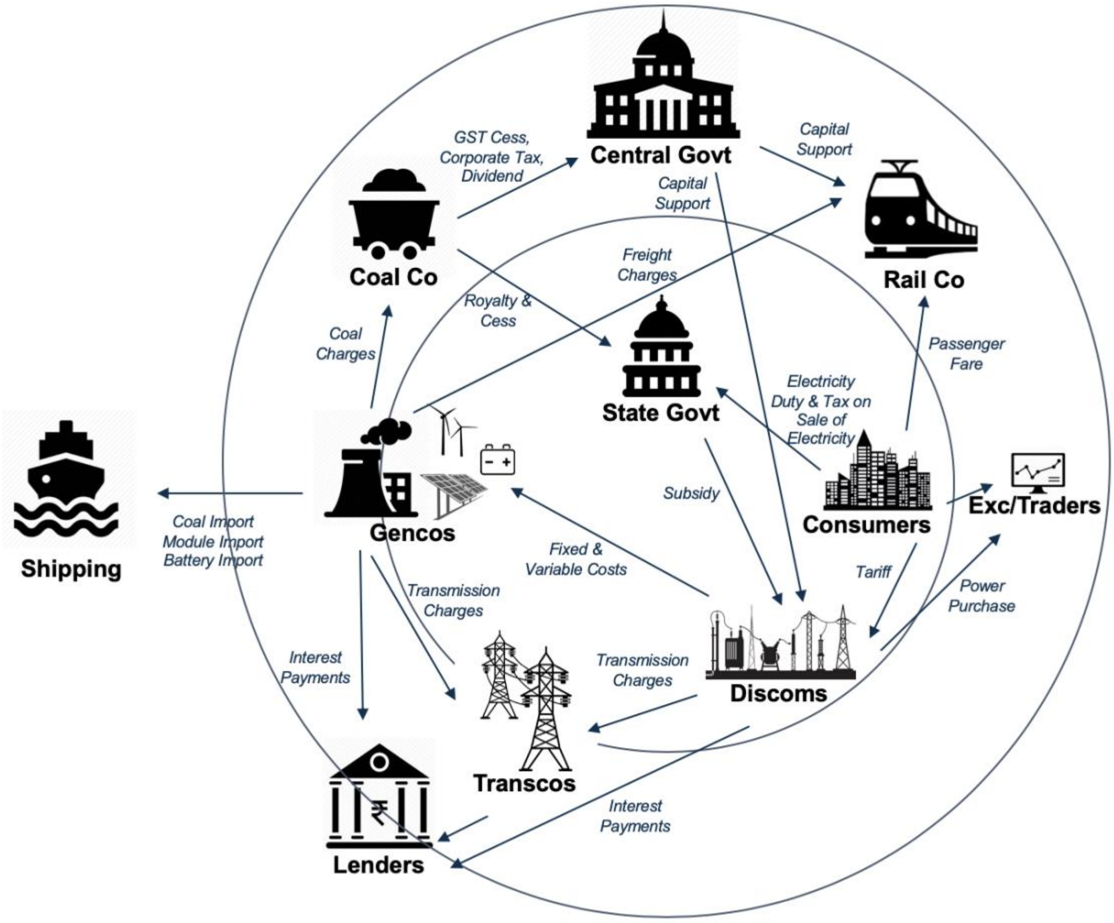
49 Ministry of Power. (2019). *PRAAPTI: Payment ratification and analysis in power procurement for bringing transparency in invoicing of generators*. PFC Consulting Ltd. Government of India. http://www.praapti.in

50 Matikainen, S. (2018). *What are stranded assets?* London School of Economics and Political Science. http://www.lse.ac.uk/GranthamInstitute/faqs/what-are-stranded-assets/

51 During this time, the average plant load factor of thermal power plants came down from 77.5% (FY10) to 59.9% (FY17).

One way to look at the big picture is to make sense of the financial linkages among various stakeholders. This analysis provides insight into why and how key stakeholders may react to a given trajectory of transition or change. Figure 13 illustrates the primary financial linkages among all stakeholders involved in the current electricity value chain.

**Figure 13. Financial linkages among key power sector stakeholders**




## Money flows to and from the central government

The central government offers support via budgetary provisions and subsidies. Indian Railways receives budgetary capital support from the central government for creation of new infrastructure. In the last interim budget, the government allotted 646 INR billion of capital support to the railways for FY20.[52] As revenues raised by the railways have decreased over the years, budgetary support has increased, almost doubling in the six-year period from FY13 to FY19 (rising from 241 INR billion in FY13 to 531 INR billion in FY19).[53] Not all of this support is to meet the needs of the power sector; however, given the importance of coal freight revenue and constant calls for better infrastructure

52 Ministry of Finance. (2019, February 1). *Budget summary with major highlights of the interim budget 2019-20* [Press release]. Government of India. http://pib.nic.in/newsite/PrintRelease.aspx?relid=187915

53 Mishra, P. (2018, September). *State of Indian Railways*. PRS Legislative Research. https://www.prsindia.org/sites/default/files/parliament_or_policy_pdfs/State%20of%20Indian%20Railways.pdf

services by the gencos, central government support for the railways likely has a significant impact on the power sector.

Together, all discoms reported a loss of 900 INR billion as of FY16.[54] Maharashtra, Uttar Pradesh and Rajasthan accounted for the largest share. Only five state utilities, in Gujarat, West Bengal, Uttarakhand, Mizoram and Puducherry, reported profits. Time and again discoms have been provided budgetary support by the central government for infrastructure upgradation schemes. In the recent past, 253 INR billion were provided to discoms under the Integrated Power Development Scheme (IPDS), primarily for strengthening the distribution network. About 334 INR billionn were provided under the Deendayal Upadhyaya Gram Jyoti Yojana scheme, with a core objective of achieving 100% rural electrification.

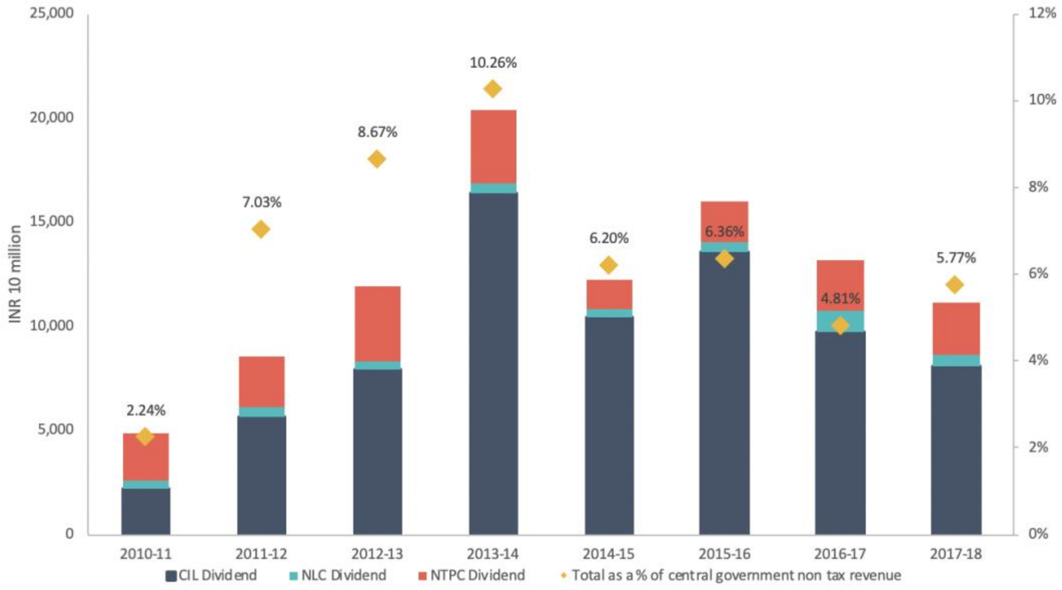
There are three sources of cash flows from other stakeholders to the central government, including (a) corporate taxes on profits, (b) dividends paid by companies where central government is a stakeholder and (c) other taxes and duties levied on business operations. Examples of 'other taxes and duties' include charges such as goods and services tax (GST) compensation cess on sale of coal, safeguard duty on solar panels and customs duty on imported coal.

**A. Corporate taxes:** Corporate tax accounts for approximately 30% of the central government's net tax revenue (see Figure 10 for what constitutes the total receipts to the government of India). Depending upon a company's turnover, the effective tax rate is anywhere between 26% and 35% for domestic companies, including various surcharges. Irrespective of ownership, a profitable company is subject to corporate taxes. Therefore, in the long run, a change in energy mix should not have an impact on the government's share of tax collection from companies involved in the electricity value chain. In the short run, however, total corporate tax collection may be impacted as a result of accounting practices, namely the depreciation benefits available to new companies (and newly created assets). Coal India and NTPC, the biggest public sector companies in the power sector, paid corporate taxes of 37 INR billion and 25 INR billionn, respectively, in FY18. The total corporate tax collected by the central government in FY18 amounted to 5,712 INR billion.

**B. Dividends:** As previously discussed, the central government is a significant shareholder in key energy sector companies, which have a history of handsome dividend payouts (see Figure 14). Since FY11, the central government has consistently disinvested part of its shareholding in these companies, reducing from 89.65% to 70.96% in CIL, from 89.32% to 84.04% in NLC and from 75% to 62.27% in NTPC. Both CIL and NTPC are part of the Nifty50 list of top companies, with a market capitalization of 1,457 INR billion and 1,336 INR billion respectively (as of 31 March 2018).

54 Ahuja, S. (2018, October 3). *Discom losses: Should power tariffs be hiked?* Ideas for India. https://www.ideasforindia.in/topics/macroeconomics/discom-losses-should-power-tariff-be-hiked.html

**Figure 14. Dividend payout history**




**C. Other revenues:** The generation, transmission and distribution of electricity are exempted from paying any GST. The mining and sale of coal pay a 5% integrated goods and services tax, as well as a GST compensation cess[55] at the rate of 400 INR/tonne. Another 5% GST is levied on the transportation of coal by rail. In FY18, Coal India alone contributed about 26% (166 INR bn) of the total GST compensation cess (626 INR bn). The GST compensation cess is also levied on certain other products, such as pan masala, aerated waters, lemonade, tobacco and gutkha (in all forms) and most types of motor vehicles. This GST compensation cess, which was effective 1 July 2017, replaced the erstwhile clean energy cess (also at 400 INR/tonne), which was levied in 2010 under the Tenth Schedule to the Finance Act.

The GST compensation cess is a type of central transfer to states that register less than 14% annual growth in their tax revenue and is a guaranteed payment for the first five years starting in FY19. PRS Legislative Research estimated that in FY19, 15 states were eligible to receive such compensation.[56] The ability of the central government to levy and collect such cess is crucial to meet its commitments to the states.

Figure 15 provides a snapshot of the transfers described above, primarily from Coal India and NTPC to the central government. Coal India and NTPC contributed approximately 3% of the total revenue receipts in FY18. The total revenue receipts (14,351 INR bn) have two subcomponents, which is nontax revenue (1,926 INR bn) and net tax revenue (12,425 INR bn).

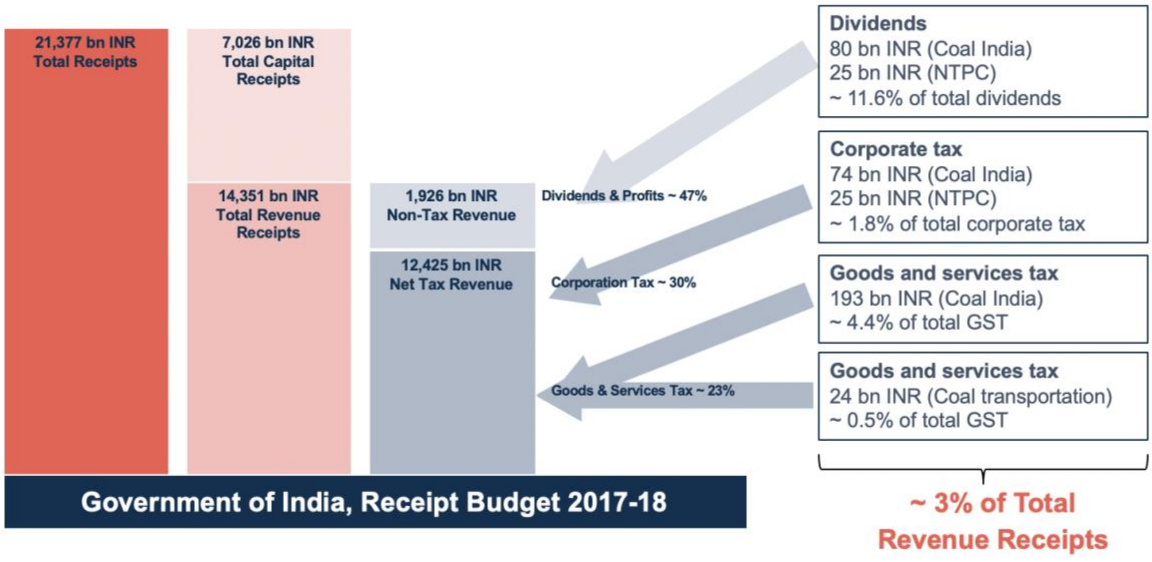
Although dividends and profits form 47% of the nontax revenue, corporate taxes contribute 30% of the net tax revenue and goods and services tax contribute about 23%. Of the total dividends and profits collected, CIL's and NTPC's share is 11.6%. Of the total corporate taxes collected by the central government in FY18, CIL's and NTPC's share together is 1.8%. And of the total GST collected by the

55 Ministry of Finance, Department of Revenue. (2017). *Notification No. 7/2017-Compensation Cess (Rate).* Government of India. https://cbic-gst.gov.in/pdf/compensation-tax/notification07-compensation-cess-rate.pdf

56 PRS Legislative Research. (2018). *State of state finances: 2018-19*. https://prsindia.org/policy/discussion-papers/state-state-finances-2018-19

central government, CIL alone contributes 4.9%, of which 4.4% comes from coal-mining operations and 0.5% comes from coal transportation. A slowdown in the business operations of these companies can therefore have a significant impact on the revenues of the central government.

**Figure 15. Coal India and NTPC contributions to government revenue receipts**




## Money flows to and from state governments

To understand the financial linkages of the power sector with the state government budgets, there is first a need to understand a state's revenue sources and expenditure goals. There are four revenue sources for state governments, which include their own tax revenue and nontax revenue, transfers received from union taxes (i.e., taxes collected by the central government) and grants or aid received from the central government. On average, states' own revenue resources (tax and nontax) contribute about 56%, while the balance are transfers from the centre (devolution — or tax transfers from the central government — and grants). Fourteen states (including most of the northeastern states) are dependent upon central transfers for more than half of their revenue. Whereas the states of Delhi (92%), Haryana (79%), Goa and Maharashtra (75%), Gujarat and Punjab (73%) and Tamil Nadu (72%) raise revenue primarily from their own taxes, all the other coal resource heavy states, except for Maharashtra, are almost equally dependent on central transfers and their own internal revenue sources (see Figure 16 for state-specific revenue source distribution).

Overall, the fiscal and revenue deficits of state governments have been increasing in recent years.[57] Schemes such as UDAY (described below) and the farm loan waiver have significantly contributed to increases in states' fiscal deficit. States' outstanding liabilities as percentage of GDP are likely to go up by 1.5% in 2016 (over 2015) and 0.7% in 2017 (over 2016).[58]

On the expenditure side, data of state finances during 2011 to 2017 indicate that, while states underspent their budgets on sectors such as urban development (20% lower than budgeted), rural

57 Chakraborty, P., Gupta, M., Chakraborty, L., & Kaur, A. (2017). *Analysis of state budgets 2017-18: Emerging issues.* National Institute of Public Finance and Policy. https://www.nipfp.org.in/media/medialibrary/2017/08/Seminar_papers.pdf

58 Reserve Bank of India. (2017). *State finances: A study of budgets.* https://www.rbi.org.in/Scripts/AnnualPublications.aspx?head=State+Finances+%3a+A+Study+of+Budgets

development and irrigation, they overspent on the energy sector (15% more than budgeted). See Figure 17 for deviation in key expenditure categories.[59]

**Figure 16. State government revenue as a percentage of own funds and transfers from centre**

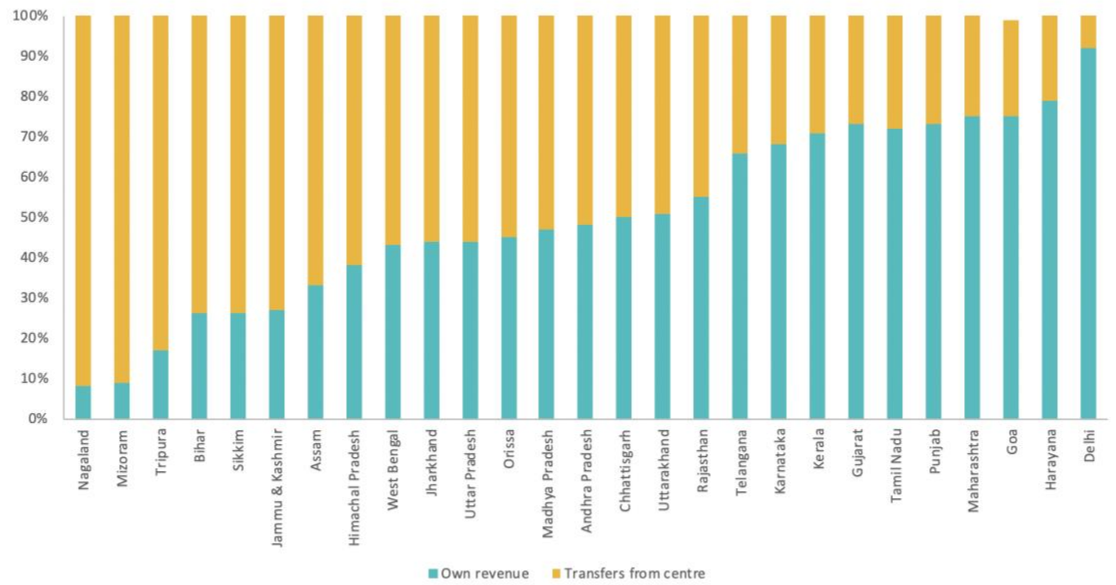



**Figure 17. Sectoral deviation in state government budgets**


The state governments levy taxes and duties on the sale of electricity to consumers and provide subsidies to discoms for keeping tariffs artificially low for certain categories of consumers, usually low-income groups and sectors such as agriculture. At times, subsidies are also provided to offer tariff rebates to industries and commercial activities for a predefined number of years. State governments also receive taxes and duties from coal-mining operations. These two sets of taxes and levies form a part of the state governments own revenue receipts.[60] Details of these linkages are described below.

59 PRS Legislative Research, 2019.

60 In FY19, revenue generated on their own constituted 52% of the total revenue receipts for states; the 48% balance was contributed by the center as part of transfers. PRS Legislative Research, 2019.

**Linkages between state government budgets to coal mining**: Coal mining contributes to states' ability to raise their own tax revenue as well as their own nontax revenue (in the form of royalties). The rate of GST on coal mining is at 5%, of which half gets deposited as a state goods and services tax (SGST) while the remaining half is deposited as a central goods and services tax (CGST). In FY18, Coal India contributed about 9 INR billion each to SGST and CGST (see Table 6 below). A 5% integrated goods and services tax (IGST) is charged on imported coal, which is deposited with the central government.

The royalty on coal mining is neither a tax, a rent nor a profit-sharing arrangement; it is a payment 'charged by the lessee to consume the wealth belonging to the lessor, which gets depleted over time'.[61] The royalty rates are fixed by the central government every three years. The state government collects it from the lessee, which could be either a public or a private company. This arrangement leads to frequent tensions between the central and state governments, owing to what should be the frequency and basis of royalty calculation. In most states, the royalty is 14% of the value of coal and has progressively subsumed most other cesses. West Bengal is the only state that is still following an older practice; instead of a royalty, it levies a cess at the rate of 25% of the value of coal.[62]

**Table 6. State revenue from coal mining**

| State | Production of coking and noncoking coal FY16 (000 tonnes) | State tax revenue FY18, revised estimates (INR bn) | SGST from CIL FY18 (INR bn) | State nontax revenue FY18, revised estimates (INR bn) | Royalty and others CIL FY18 (INR bn) |
|---|---|---|---|---|---|
| Odisha | 138,461 | 265.20 | 1.72 | 90.00 | 23.13 |
| Chhattisgarh | 130,605 | 198.95 | 1.90 | 63.40 | 29.52 |
| Jharkhand | 121,067 | 411.12 | 2.11 | 112.57 | 37.64 |
| Madhya Pradesh | 107,714 | 463.38 | 1.42 | 95.21 | 22.00 |
| Maharashtra | 38,351 | 1,649.79 | 1.02 | 216.71 | 12.87 |
| West Bengal | 25,751 | 577.01 | 0.35 | 31.17 | 16.18 |
| Uttar Pradesh | 12,689 | 973.93 | 0.38 | 197.95 | 6.17 |
| Assam | 487 | 132.16 | 0.04 | 40.72 | 0.62 |

Royalty is recognized as one of the revenue-maximizing sources for coal-rich states, especially given that these mineral-rich states (primarily Odisha, Chhattisgarh and Jharkhand) are relatively financially poor.[63] A higher royalty also increases the power procurement costs (assuming mostly coal-fired power plants), and thus it may lead to an increased electricity supply subsidy burden on the

61 Rao, H. (2003). *Economic and fiscal impact of royalty rates of coal and lignite in India.* Institute for Social and Economic Change. http://planningcommission.gov.in/reports/sereport/ser/stdy_coal.pdf

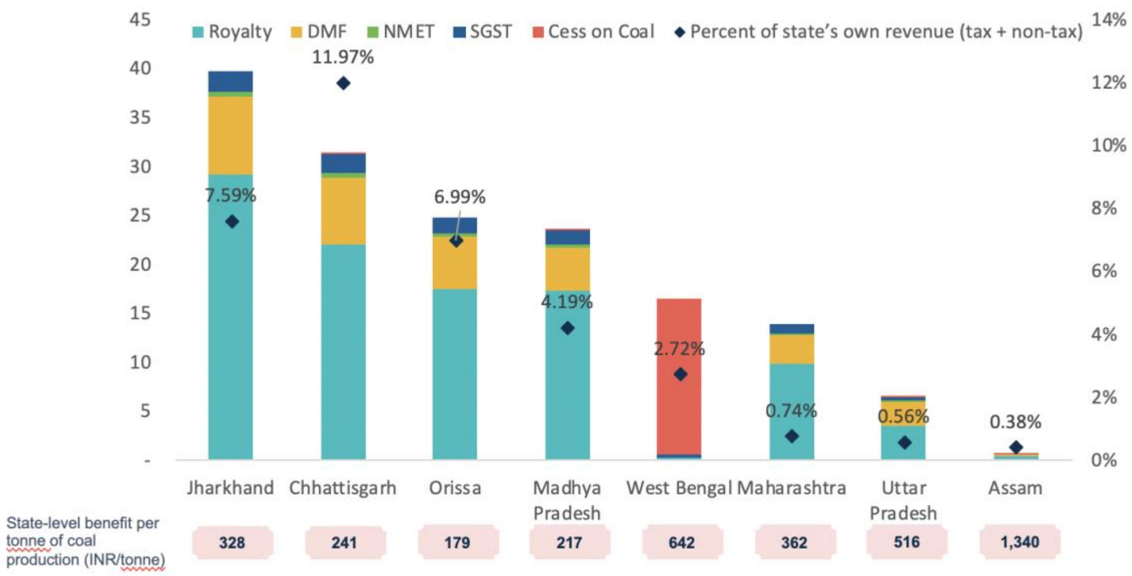
62 'The Cess Acts of Government of West Bengal are subjudice before the Supreme Court of India. The State Government has filed a special leave petition in the Supreme Court. However, the 1981 coal royalty rates (average Rs. 5.30 per tonne) are still applicable to West Bengal. The Government of West Bengal is also levying coal Cess at the rate of 25% of the coal prices ( earlier it was as high as 45%) While the average rate of coal royalty to the coal prices vary from 11 to 14% in the coal producing States other than West Bengal, the consolidated rates of coal royalty and coal Cess in West Bengal to the coal prices is about 26% i.e., the highest in the country'. Rao, 2003

63 World Bank. (2018). *India states brief.* https://www.worldbank.org/en/news/feature/2016/05/26/india-states-briefs

state. Also, too high a royalty and other charges result in lower profits for Coal India (as their costs increase while the price may or may not increase in proportion), thereby leading to lower corporate taxes and dividend payouts to the central government.

The District Minerals Foundation (DMF) is a public trust set up under the provisions of the Mines and Minerals (Development and Regulation) Act, 2015, to make funds available for districts impacted by mining. These funds are not available to general state budgets. This restriction is seen as essential so that a fair share of revenue is transferred to affected tribal communities in coal-producing districts. The rules for setting up the DMF trust and for use of its funds are left to the state governments. Not much literature is available to assess the benefits of DMF funds,[64] and some early reports suggest that these funds have been used for other purposes by state governments.[65] The National Mineral Exploration Trust (NMET) was also created under a provision of the Mines and Minerals Act, 2015, and is levied at the rate of 2% of the state royalty. The NMET Fund is supervised by the member secretary of the Ministry of Mines. See Figure 18 for a breakdown of contributions from each type of levies as reported by Coal India.

**Figure 18. Contribution of Coal India to selected state government budgets**




**Linkages of state government budgets to power distribution**: Following adoption of the Electricity Act, 2003, most states, which earlier had an integrated state-government-owned electricity board, were asked to unbundle. Subsequently, separate entities were created for distribution (wires and supply), transmission and generation of electricity, with each function managed by a different state-government-owned company. These companies are regulated by a state electricity regulatory commission. Even though they are governed by regulators and have to abide by the rules of the Companies Act, 2015, it is widely known and accepted that the political economy plays a major role in

64 Mishra, P.R. (2016, November). *Fair sharing of mining revenue for the tribals*. Oxfam India. https://www.oxfamindia.org/blog/fair-sharing-mining-revenue-tribals

65 Money Control. (2019, 7 March). *Raman Singh govt diverted welfare funds to Ujjwala scheme in Chhattisgarh: Report.* https://www.moneycontrol.com/news/india/raman-singh-govt-diverted-welfare-funds-to-ujjwala-scheme-in-chhattisgarh-report-3618451.html

their day-to-day business activities, including tariff-setting processes and efficiency improvement decisions.

Over the last several years, various fiscal programs have been rolled out to deal with the financial stress in the distribution and supply of electricity. Particularly new is the Ujwal Discom Assurance Yojana (UDAY), which was launched in November 2015.[66] Under UDAY, state governments agreed to take over 75% of discoms' debt and convert it into state nonstatutory liquidity ratio bonds, with a commitment from the discoms that they will improve their operational performance. As of May 2018, 86% of UDAY bonds totaling up to 2,320 INR billion have been issued by state governments. A majority of the financial and operational efficiency parameters, however, have not been met by the participating states.[67]

Insufficient tariff hikes over the years for low-income and agriculture consumers have led to ever an increasing subsidy burden on state governments. Often the states agree to a particular subsidy amount to keep tariffs in check but afterwards fail to disburse the complete amount, further straining discom finances.[68]. The subsidy burden of all discoms was 577 INR billion in FY16 and increased to 850 INR billion in FY19.[69]

Every state government levies taxes (charged as a percentage of the total bill) and duties (charged on a volumetric basis) on the sale of electricity under a state-specific law or rule. The rate of these levies differs from state to state and is particularly high in the states of Gujarat (20%) and Maharashtra (15%). Some states levy only one charge, for example, either a tax on the sale of electricity or an electricity duty. These are collected via the electricity bills by discoms and passed on to the state governments. In the absence of enough reporting information on these taxes, it is hard to estimate the total amount of taxes and duties collected.

The stakeholders in the electricity value chain are intricately linked together via a web of government ownership and state and central taxes, levies and royalties, along with transfers from the centre and subsidies for certain customers. An understanding of these interlinkages is critical to understanding the impact that India's energy transition will have and to assessing the possible trade-offs to ensure a win-win transition. In the next chapter, we highlight the indirect impacts of the energy transition on key stakeholders.

66 Ministry of Finance. (n.d.). *UDAY dashboard*. Government of India. www.uday.gov.in

67 Kaur, A., & Chakraborty, L. (2018). *UDAY power debt in retrospect and prospects: Analyzing the efficiency parameters.* Working Paper series no. 244. National Institute of Public Finance and Policy. https://www.nipfp.org.in/publications/working-papers/1839/

68 World Bank. (2014). *More power to India: The challenge of electricity distribution.* http://documents.worldbank.org/curated/en/815021468042283537/More-power-to-India-the-challenge-of-electricity-distribution

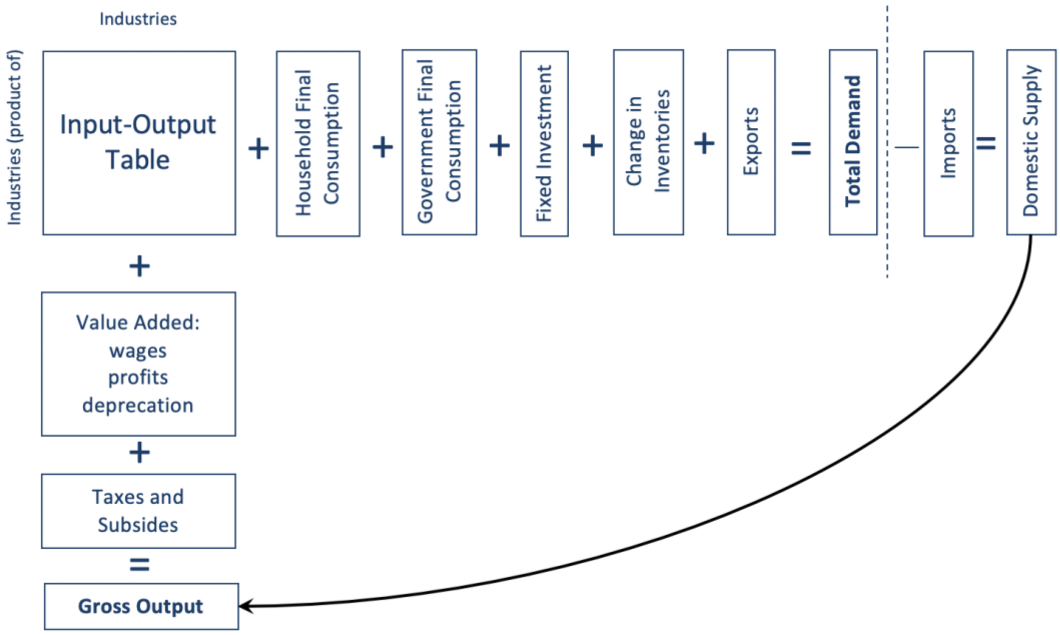
69 Financial Express Bureau. (2018, 10 July). *Discoms' subsidy reliance seen rising to Rs 85,000 cr.* https://www.financialexpress.com/economy/discoms-subsidy-reliance-seen-rising-to-85000-cr/1238046/

# Chapter 4: What are the indirect impacts of the energy transition?

Coal-based generation is well embedded in the Indian economy with strong backwards, forwards and cross-sectoral supply and value chain linkages. Because central and state governments have major stakes in the Indian power sector, an energy transition to renewables will impact them in both positive and negative ways. More importantly, the channels through which these impacts are felt may vary in fundamental ways for different stakeholders. Consequently, it is crucial for stakeholders to assess the direct and indirect impacts of the transition to develop a robust risk mitigation strategy.

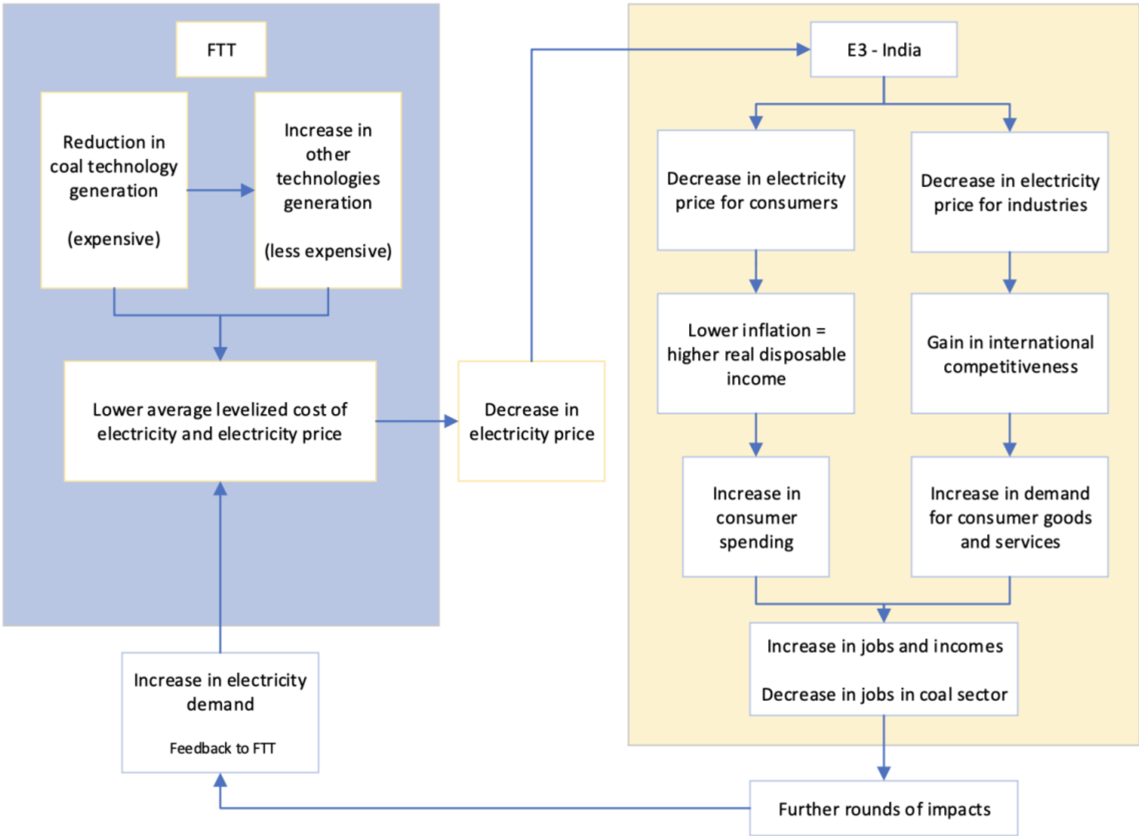
We assess the effects of incremental renewable energy deployment under the high-renewables and low-renewables scenarios using the E3-India model. The model integrates macroeconometric simulation through a unique demand-driven, disequilibrium framework, which allows us to assess the dynamics of power sector transition and the concomitant effects that flow through the entire economy. The model combines a standard system of national and state accounts with a series of econometric equations to capture the behavioural relationships and responses of the economy to policy (Figure 19). Further, the top-down economy model is fully integrated with a bottom-up future technology transition (FTT) energy model. The FTT module effectively captures the dynamics of incremental deflationary solar and wind addition in the generation mix using a novel framework that combines technology learning curves with cost supply curves to estimate the emerging levelized cost of electricity at a given point. Annexure 4 provides more detail on the E3-India model.

**Figure 19. E3-India: Economy module**




The model estimates the impacts of greater renewable capacity on the overall economy by two routes: first by assessing the impact of the reduction in the cost of electricity and second by assessing the effects of incremental investment in the renewable energy sector. The reduction in the cost of electricity generation leads to a decrease in the input price of electricity for all other sectors of the economy as illustrated in Figure 20. The overall decrease in the cost of electricity generation translates into a decrease in the price of electricity for all consumers and industries, which in turn leads to an increase in electricity consumption and other goods, along with favorable impacts on household incomes.

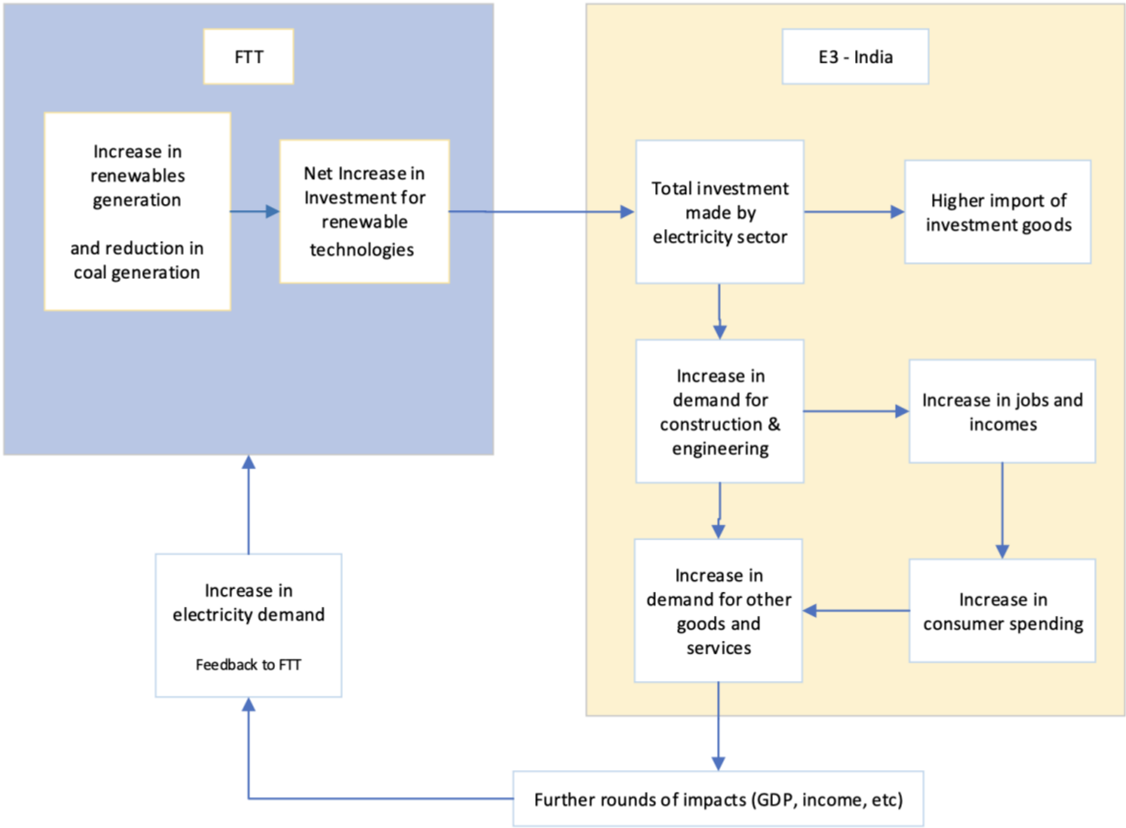
**Figure 20. Electricity price effects across the economy**




Second, the effects of incremental investment in renewable energy are captured by E3-India as delineated in Figure 21. As coal is replaced with renewable energy, the net increase in total investments in renewable energy technologies is estimated. The investments[70] will lead to increases in the direct and indirect demand in associated sectors like construction and engineering, along with concomitant changes in employment and income. This flows into the economy as changes in consumer spending and increased demand for consumer goods. A possible positive economic effect again leads to an increase in energy demand to be met by more generation from the power sector.

70 One major caveat for this analysis is that investments in solar PV technologies are in terms of utility scale generation. The modelling framework at the moment does not distinguish between large scale and distributed PV. We understand that cost of technology and employment vary significantly for the two categories and that the estimates will change with inclusion of incremental roof top PV.

**Figure 21. Investment impacts across the economy**

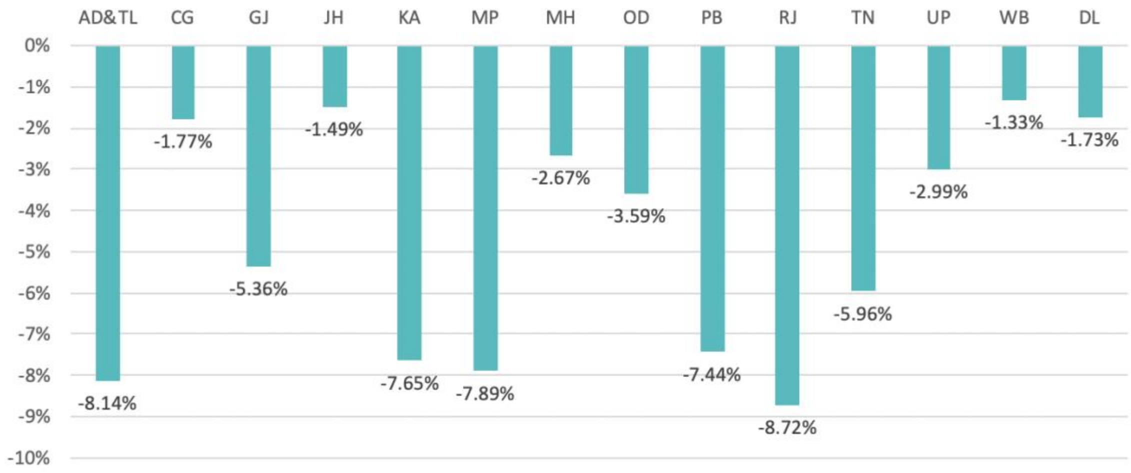



We estimate the impacts of the high-renewables scenario (HR) relative to the low-renewables (LR) scenario on key economic and energy parameters like GDP, employment and consumption, along with price and consumption of electricity at both the national and regional level by 2030. Further, the distributional impacts of greater renewable deployment are also assessed in terms of change in disposable income across rural and urban household quintiles both at the national and state level. We highlight the impacts of the scenarios as the difference in value or percentage between the low- and high-renewables scenario in the year 2030. The estimated impacts in 2030 are cumulative as the ongoing impact of investments made in prior years are also captured by E3-India.

## Cost of electricity production

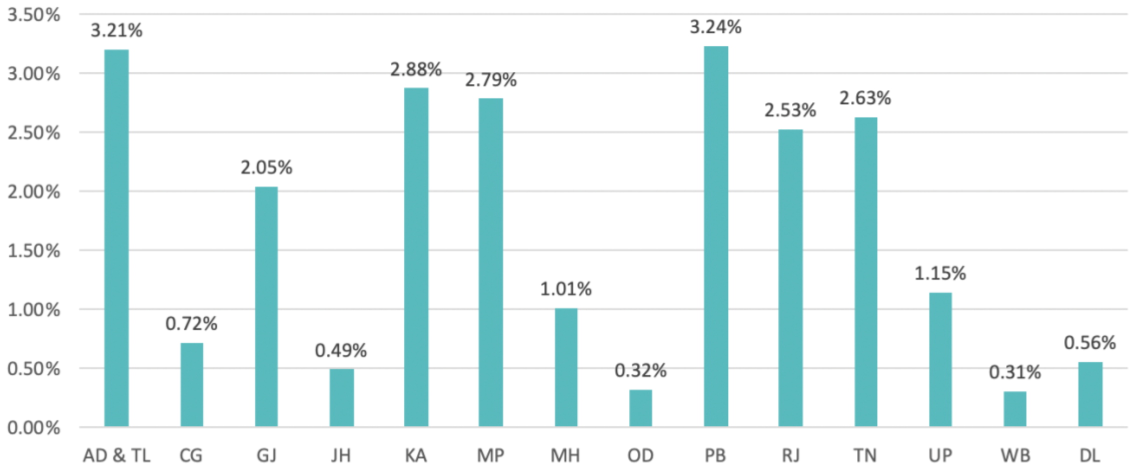
The high-renewables scenario is characterized by the incremental addition of deflationary solar and wind in the generation mix. This leads to an overall economy-wide reduction in the average cost of electricity by 4.13% relative to the low-renewables scenario. Depending on the geography of a given state and how much renewable infrastructure has been added, the reduction in electricity cost can range from 8.7% in a high solar insolation state such as Rajasthan to 1.7% for a coal-producing state such as Chhattisgarh (see Figure 22). Note that this data illustrates the cost of electricity and not the tariffs levied on consumers. Retail tariffs are set by state electricity regulatory commissions where various socioeconomic objectives are considered for levying subsidies and cross subsidies along different consumer categories like agriculture, household, industry and services.

**Figure 22. Decrease in electricity cost in the HR scenario relative to the LR scenario in 2030**




A key consequence of lower electricity costs is the substantial increase in electricity consumption nationally and across all states. The largest increases are observed in Punjab (3.24%), Andhra Pradesh (3.21%), Karnataka (2.88%) and Rajasthan (2.53%), which also have the greatest decrease in electricity prices (Figure 23), indicating a clear price-demand elasticity and latent demand for cheap electricity across the states.

**Figure 23. Increase in electricity consumption in the HR scenario relative to the LR scenario in 2030**




## Impact on GDP and employment

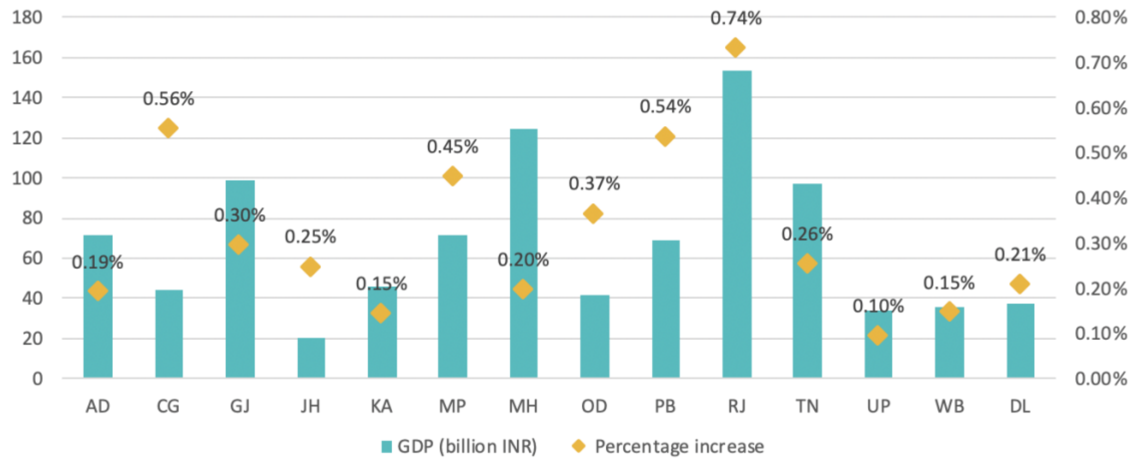
Increased consumption and investments leads to higher GDP and employment in 2030 (0.28% and 0.048%, respectively) under the high-renewables scenario (Table 7) compared to the low-renewables scenario at the national level. A higher GDP and employment growth means higher tax revenues. This indicates the potential to offset lower revenues received by central and state governments directly from coal-related institutions, as described in Chapter 3.

**Table 7. Changes in national-level GDP and employment**

| | GDP (INR bn) | Employment (000) |
|---|---|---|
| Increase under HR relative to LR | 1021.3 | 375.81 |
| Percent change | 0.28% | 0.05% |

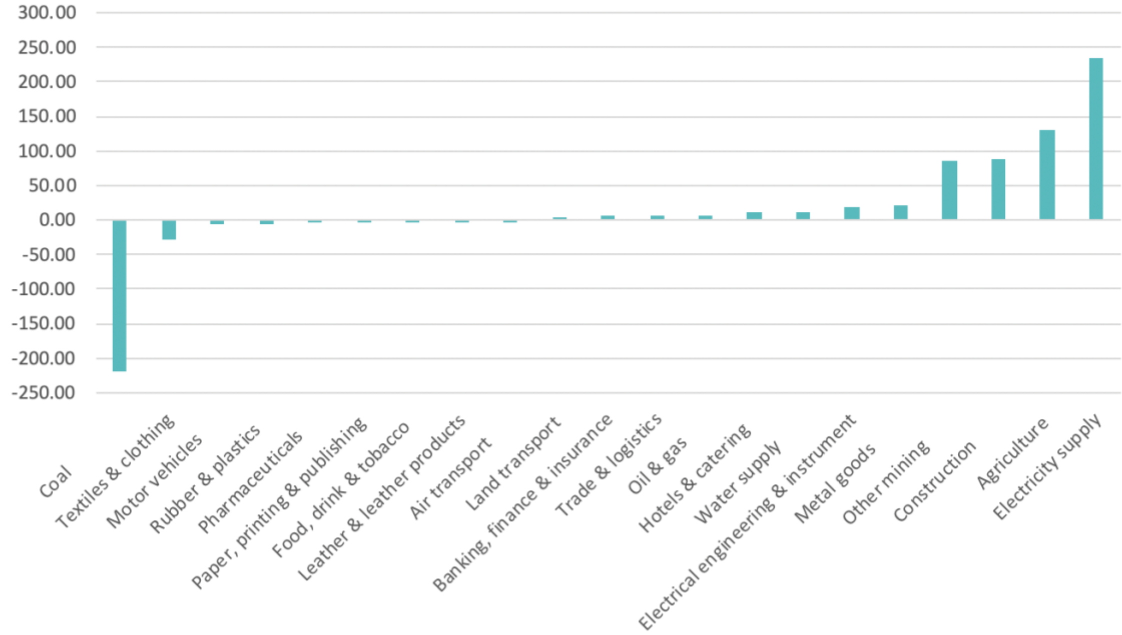
The higher GDP also impacts states, with Rajasthan, Punjab and Chhattisgarh seeing a 0.5% increase in GDP in 2030 under the high-renewables scenario; however, large states, such as Maharashtra, Andhra Pradesh and Telangana, Karnataka, West Bengal, Uttar Pradesh and Delhi, see less than 0.2% growth in GDP by 2030 (Figure 24).

**Figure 24. The HR scenario GDP in 2030 and percentage increase relative to the LR scenario**




Employment across sectors reveals an overall net increase in employment by 375,800 in the high-renewables scenario. The key sectors showing an increase in net employment generation include electricity supply (+14.12%), oil and gas (+10.14%), other mining (+ 2.81%), water supply (6.9%) and electrical engineering (+0.91%). Coal mining sees the largest reductions in employment at 15.21% relative to the low-renewables scenario. Other sectors, including rubber and plastic, textile, leather and motor vehicles, experience marginal decreases of 0.02-0.27% (Figure 25).

**Figure 25. Sector-wise change in employment (000) in 2030 under the HR scenario**




Employment is relatively higher in the high-renewables scenario for 2030 across most states except Maharashtra, Andhra Pradesh and Telangana and Odisha (Figure 26). A closer look reveals, however, that this negative impact is not felt equally across all coal-mining states. The lower employment in Maharashtra, Andhra Pradesh and Telangana[71] and Odisha is driven by reduced outputs from the indigenous coal sector in these states, which is not competitive with coal mined in other states, such as Chhattisgarh and Jharkhand. Aggregate coal use in the high-renewables scenario is 8% lower than under the low-renewables scenario. Coal output from key coal-producing states, such as Chhattisgarh and Jharkhand, is lower by only 1.04% and 1.08%, respectively, while coal output from Maharashtra, Andhra Pradesh and Telangana and Odisha drops down by 42.6%, 98.2% and 6.3%, respectively, resulting in lower employment in that sector. As the overall contribution of coal mining to the economies of these three states is relatively small, the overall GDP growth trajectory of these three states continues to be positive.

71 Andhra Pradesh and Telangana are treated as one state in E3-India and are reported together in results; Telangana, a new state, was split out of Andhra Pradesh in 2014. Separate historic data series for the modelling were not available.

**Figure 26. The HR scenario employment in 2030 and percentage change from the LR scenario**


## Change in income across households

From the perspective of households (Figure 27), cheaper electricity and the expansive impact of larger overall investments drive a substantially higher level of income across all states under the high-renewables scenario relative to the low-renewables scenario. In the high-renewables scenario, an equitable increase in income is observed for rural and urban low-income, middle-income and high-income households, when disaggregated across the states (Table 8).

**Figure 27. Percent change in household incomes under the HR scenario relative to the LR scenario in 2030**

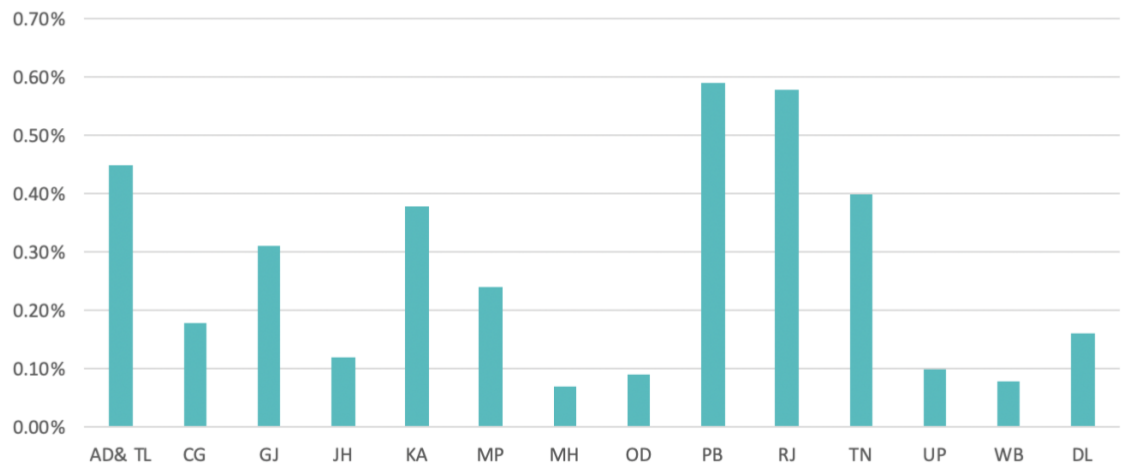


**Table 8. Percentage change in household income across rural and urban households**

| | Rural Households | | | Urban Households | | |
|---|---|---|---|---|---|---|
| | R1 low income | R2 middle income | R3 high income | U1 low income | U2 middle income | U3 high income |
| AD&TL | 0.632 | 0.683 | 0.605 | 0.424 | 0.431 | 0.351 |
| CH | 0.165 | 0.169 | 0.170 | 0.171 | 0.181 | 0.177 |
| GJ | 0.311 | 0.320 | 0.319 | 0.314 | 0.311 | 0.294 |
| JH | 0.116 | 0.118 | 0.128 | 0.116 | 0.120 | 0.124 |
| KA | 0.367 | 0.400 | 0.414 | 0.369 | 0.359 | 0.356 |
| MP | 0.243 | 0.249 | 0.253 | 0.234 | 0.232 | 0.197 |
| MH | 0.069 | 0.076 | 0.070 | 0.063 | 0.066 | 0.072 |
| OD | 0.117 | 0.106 | 0.100 | 0.098 | 0.099 | 0.086 |
| PN | 0.551 | 0.556 | 0.587 | 0.562 | 0.594 | 0.571 |
| RJ | 0.611 | 0.621 | 0.612 | 0.598 | 0.577 | 0.540 |
| TN | 0.145 | 0.151 | 0.156 | 0.146 | 0.155 | 0.156 |
| UP | 0.081 | 0.082 | 0.101 | 0.079 | 0.083 | 0.123 |
| WB | 0.050 | 0.061 | 0.072 | 0.061 | 0.066 | 0.084 |
| DL | 0.145 | 0.151 | 0.156 | 0.146 | 0.155 | 0.156 |

| | |
|---|---|
| 0-0.09 | Marginal |
| 0.1-0.20 | Low |
| 0.21-0.60 | Moderate |
| 0.61-1.00 | High |

Higher real disposable income, along with a reduction in electricity costs, leads to increased electricity use in the household energy mix for the high-renewables scenario. There is an average increase of 1.6% in electricity consumption of households. This is coupled with a reduction in consumption of liquid fuels (-0.65%).[72] The households also show a reduction in consumption of gaseous fuels (-1.01%).[73] These trends indicate a positive feedback loop towards cleaner energy transitions in

72 The liquid fuel in Indian households is primarily kerosene procured through a public distribution system at a subsidized rate and is used for lighting and cooking purposes.

73 LPG cylinders are provisioned at a subsidized rate for Indian households and are used for water heating and cooking purposes.

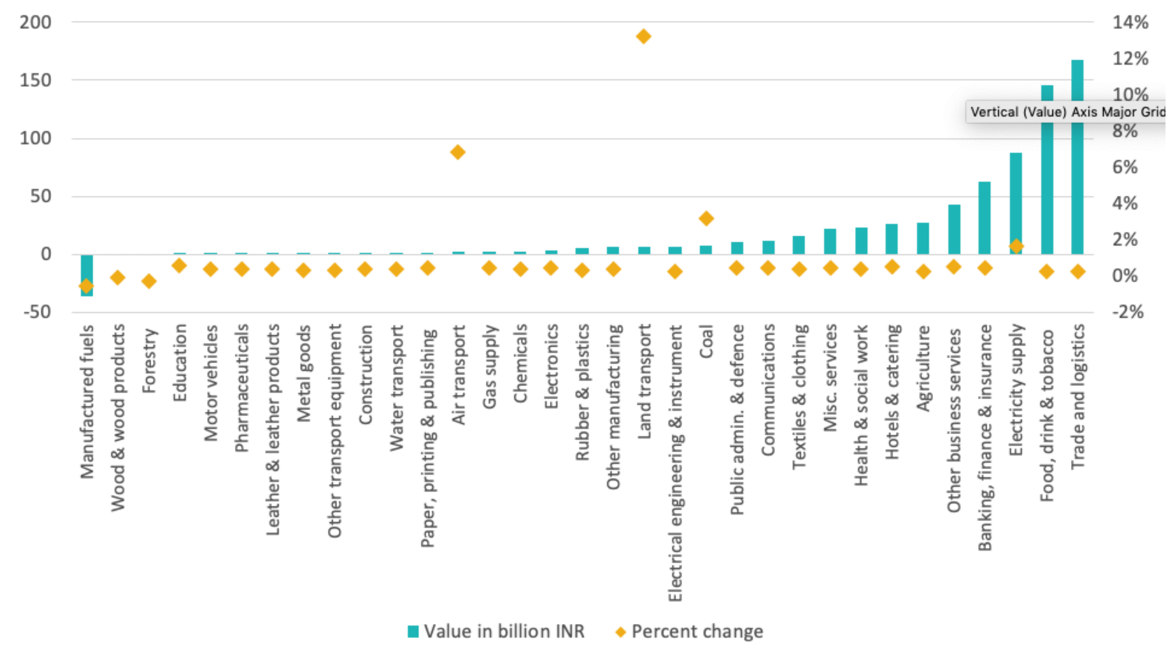
household energy use and also an opportunity to reduce the burden of fossil-fuel subsidies that the government provides to households.74

## Change in consumption across state and sector

Higher real disposable income leads to higher consumer spending, which in turn yields higher consumption in several sectors of the economy (Figure 28). The key sectors showing higher consumption due to increased demand under the HR scenario include trade and logistics; food, drink and tobacco; electricity supply; banking, finance and insurance; land and air transport; health; and education. Cross-sector rebound effects in terms of increase in energy use in transportation sector are also observed under the HR scenario relative to the LR scenario in 2030.

Consumption of coke and wood decreases while coal consumption increases by 3%, indicating fuel substitution away from coke and wood to coal in the HR scenario. This fuel substitution occurs because coal consumption of the power sector is lower in the HR scenario and gets reallocated to other sectors of economy.

**Figure 28. Increase in consumption (INR bn) under the HR scenario relative to the LR scenario**




The trend of increased consumption across sectors closely matches the reduction in electricity costs across states (see Table 9). Thus, the states of Punjab, Rajasthan and Tamil Nadu show the greatest increase in consumption followed by Karnataka and Gujarat. The dominant trend of coke to coal substitution is also evident in Gujarat, Jharkhand, Maharashtra, Punjab, Rajasthan and Uttar Pradesh. The state of Andhra Pradesh and Telangana shows a trend of decreased consumption of

74 The total subsidy on publicly distributed kerosene and LPG distribution stands at 59.5 billion and 315 billion, respectively, for FY 2018-19. Abdi, B. (2019, 12 July). *India saved Rs 59,000 crore of cooking gas subsidies due to direct transfer.* ET EnergyWorld. https://energy.economictimes.indiatimes.com/news/oil-and-gas/india-saved-rs-59000-crore-of-cooking-gas-subsidies-due-to-direct-transfer/70193258

primary goods but an increase in consumption of services, indicating a discernible trend in the growth trajectory.

## Summary of key findings

- Higher renewable energy in the energy mix leads to cheaper electricity,which in turn results in higher electricity demand across all states.
- Cheaper electricity in the high-renewables scenario leads to higher real disposable income, culminating in higher consumer spending across all states, rural and urban areas and income quintiles.
- Cheaper electricity also leads to a shift away from subsidized fossil-fuel use (kerosene and LPG) in the household energy mix to a higher use of electricity.
- Overall GDP and employment are higher in the high-renewables scenario relative to the low-renewables scenario.
- Sectoral impacts are diverse with consumption decreasing in specific sectors like manufactured fuel due to fuel substitution in multiple states.

**Table 9. Change in consumption across sectors and states**

| Sectors/States | AD&TL | CG | GJ | JH | KA | MP | MH | OD | PB | RJ | TN | UP | WB | DL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | -0.33 | -0.08 | 8.95 | 0.32 | 0.08 | 0.02 | 1.72 | 0.22 | 1.15 | 3.54 | 3.52 | 0.32 | 0.88 | 0.23 |
| Coal | -0.36 | -0.08 | 1.19 | 0.12 | -0.25 | 0.07 | 0.34 | 0.03 | 0.59 | 2.12 | 0.62 | 0.15 | 0.07 | 0.23 |
| Food, drink, tobacco | -1.10 | -0.24 | 45.12 | 1.70 | 1.39 | 0.48 | 7.26 | 1.25 | 6.16 | 19.82 | 20.05 | 1.95 | 4.72 | 1.32 |
| Textiles, clothing | 0.74 | 0.13 | 1.86 | 0.25 | -0.49 | 0.39 | 0.97 | 0.17 | 0.64 | 2.21 | 3.51 | 0.64 | 0.17 | 0.46 |
| Paper, printing, publishing | 0.06 | 0.03 | 0.14 | 0.01 | 0.05 | 0.01 | 0.02 | 0.02 | 0.14 | 0.48 | 0.01 | 0.12 | 0.10 | 0.02 |
| Manufactured fuels | -11.28 | -0.09 | -2.77 | -0.28 | -4.02 | 0.20 | -3.97 | 0.03 | -3.40 | -6.96 | -1.42 | -1.69 | 0.07 | 0.19 |
| Chemicals | 0.16 | 0.04 | 0.32 | 0.01 | 0.13 | 0.01 | 0.09 | 0.03 | 0.24 | 0.50 | 0.25 | 0.14 | 0.16 | 0.03 |
| Rubber, plastics | 0.40 | 0.05 | 0.72 | 0.04 | 0.19 | -0.02 | 0.30 | 0.08 | 0.46 | 0.44 | 0.96 | 0.14 | 0.33 | 0.09 |
| Electronics | 0.14 | 0.07 | 0.30 | 0.01 | 0.11 | 0.01 | 0.04 | 0.03 | 0.29 | 0.92 | 0.06 | 0.22 | 0.20 | 0.03 |
| Electrical engineering, instruments | 0.19 | 0.13 | 0.59 | 0.09 | -0.42 | -0.17 | 0.71 | 0.21 | 0.38 | 0.70 | 0.80 | 0.25 | 0.37 | 0.25 |
| Motor vehicles | 0.05 | 0.00 | 0.08 | 0.00 | 0.04 | 0.00 | 0.02 | 0.00 | 0.05 | 0.03 | 0.11 | 0.01 | 0.03 | 0.00 |
| Other manufacturing | 0.62 | 0.06 | 0.45 | 0.07 | 0.20 | 0.08 | 0.37 | 0.07 | 0.44 | 0.66 | 0.83 | 0.31 | 0.23 | 0.14 |
| Electricity supply | 18.80 | -0.12 | 9.05 | 1.33 | 8.29 | 0.15 | 8.37 | 0.04 | 7.41 | 9.99 | 14.12 | 1.03 | 0.10 | 0.32 |
| Construction | 0.01 | 0.00 | 0.13 | 0.02 | 0.02 | 0.02 | 0.21 | 0.00 | 0.06 | 0.08 | 0.08 | 0.09 | 0.06 | 0.06 |
| Trade, logistics | 0.27 | 0.93 | 36.92 | 1.96 | 0.61 | 1.49 | 5.82 | 2.11 | 8.19 | 25.29 | 26.89 | 4.57 | 6.30 | 2.93 |
| Hotels, catering | 2.15 | -0.28 | 3.79 | 0.27 | 2.21 | 0.81 | -1.72 | 0.38 | 1.38 | 4.13 | 5.94 | 0.47 | 0.69 | 0.64 |
| Land transport | -0.30 | -0.07 | 1.07 | 0.11 | -0.23 | 0.06 | 0.29 | 0.02 | 0.53 | 1.86 | 0.61 | 0.13 | 0.07 | 0.21 |
| Banking, finance, insurance | 8.62 | 0.40 | 3.80 | 0.79 | 3.74 | 1.80 | 3.69 | 0.31 | 4.76 | 5.83 | 9.76 | 3.65 | 1.73 | 1.37 |
| Education | 0.05 | 0.00 | 0.04 | 0.00 | 0.02 | 0.01 | 0.01 | 0.00 | 0.03 | 0.04 | 0.06 | 0.01 | 0.01 | 0.01 |
| Health care, social work | 2.48 | 0.03 | 3.01 | 0.16 | 1.58 | 0.30 | 0.84 | 0.20 | 2.15 | 2.17 | 4.17 | 0.69 | 1.17 | 0.35 |

| | |
|---|---|
| Negative | Negative |
| 0-0.5 | Marginal |
| 0.6-1 | Moderate |
| Above 1% | High |

# Synthesis

This analysis reveals an intrinsic value in accelerating the transition to renewables not only for the Indian power sector but for the economy as a whole. Higher renewables in the energy mix leads to an incremental reduction in the cost of electricity generation across all states. With state-owned discoms expected to reach more than 2.6 INR trillion[75] of debt in the current fiscal year, committing to a trajectory that reduces generation costs provides an opportunity to significantly improve discom balance sheets by appropriating the accumulated regulatory assets. Further, as decreasing production costs are passed through to consumers, it can help alleviate the prevailing barriers to access and affordability of electricity services.

As electricity becomes cheaper in the high-renewables scenario, there is a substantial increase in demand across states. The robust price-demand elasticity dynamics of the states create value for both household consumers and production sectors in the economy. Cheaper electricity leads to higher disposable income, culminating in higher consumer spending across all states, rural and urban areas and income terciles, further increasing the final demand for electricity and other consumable goods. Thus, committing to the high-renewables trajectory can help to encourage robust growth in the power sector by rejuvenating demand.

Coupled with increased electricity demand is a decrease in the consumption of manufactured fuel due to fuel substitution in multiple states under the high-renewables scenario. Further, the results also reveal a discernible pattern of household fuel switching from kerosene and gas to electricity. This has the potential to reduce dependency on subsidized fossil fuels and thereby reduce the government's subsidy burden. In addition, this fuel-switching creates a cleaner profile for household energy use in India.

The flow of investments improves under the high-renewables scenario, leading to an overall increase in GDP and employment. The GDP impacts across all states are positive, but this transition pathway sees a redistribution in employment across sectors and states. Under the high-renewables scenario, investment impacts lead to increases in employment for both the electricity supply and oil and gas sectors by 14.12% and 10.14%, respectively. The greater investment in renewable energy is also coupled with increased investment in flexible generation, which gets captured by higher investments in the oil and gas sector.[76]

Under the high-renewables scenario, the electricity sector expands across all states due to greater incremental renewable capacity addition. The restructuring of the coal supply chain under cost pressure for some states like Maharashtra and Andhra Pradesh and Telangana also plays a role in this expansion. This analysis considers only utility-scale solar PV investments in India. The government of India has special schemes to promote roof-top solar along with other specific incentives for key

75 Thomas, T. (2019, May). *Discom debt to swing back to pre-UDAY level of ₹2.6 lakh crore in FY20.* LiveMint. https://www.livemint.com/industry/energy/discom-debt-to-swing-back-to-pre-uday-level-of-rs-2-6-lakh-crore-in-fy20-crisil-1557139427731.html

76 Note that the high-renewables scenario does not include battery storage, as is the assumption in the CEA study, which emphasized the need for flexibility; however, the capacity and generation mix remain comparable, making it a closely proximate plausible scenario to the CEA analysis.

sectors like agriculture.[77] These focused incentives will further improve the prospects of regional economic growth and development across states. We plan to study these effects in the future.

The rapid and substantial addition of renewables will not only create new venues for investment in the Indian power sector but may also destabilize the complex set of institutional structures and long-lived financial and economic linkages associated with thermal power generation. Through this analysis, we estimated the direct and indirect economic impacts associated with incremental renewable capacity addition at the state level and thereby reflect on key trade-offs associated with India's power sector transition.

77 Ministry of New and Renewable Energy. (2019). *New scheme for farmers for installation of solar pumps and grid connected solar power plants.* Government of India. https://mnre.gov.in/sites/default/files/webform/notices/New%20Scheme%20for%20Farmers%20for%20Installation%20of%20Solar%20Pumps%20and%20Grid%20Connected%20Solar%20Power%20Plants.pdf

# Chapter 5: What are the key trade-offs?

The dynamics of incumbent thermal power generation in India has evolved over time through well-articulated checks and balances, along with substantial institutional support by both the central and state governments. The key players, including CIL (Coal India Limited), NTPC and Indian Railways, are state-owned entities that not only receive direct and indirect fiscal and economic incentives to provide cheap power but also contribute substantially to the revenue streams of both central and some state governments. Greater inclusion of renewables in the energy mix will fundamentally change these dynamics. In fact, the power sector itself is expected to undergo a structural change by becoming more diffused and decentralized with an array of disparate stakeholders and service providers in multiple supply chains.

The age of cheap renewables makes the transition in the Indian power sector inevitable. Endorsement and management of change will require proactive planning and action by all stakeholders. Based on the analysis in this study, the key trade-offs and opportunities that policymakers and stakeholders will need to deliberate on are:

- Higher direct revenue from institutions such as CIL and NTPC for central government and state governments under the low-renewables scenario versus higher revenue from taxes due to higher GDP, employment and household income under the high-renewables scenario.
- Higher employment in specific locations and specific sectors (e.g., coal mining in MH) under the low-renewables scenario versus higher employment in other states and sectors (and in aggregate at a national level and in all sectors) under the high-renewables scenario.
- Higher cross-subsidy from coal transport for lower passenger fares under the low-renewables scenarios versus higher household incomes across all states, rural and urban and all income classes (especially poor households), which may allow for higher passenger fares under the high-renewables scenario.
- Higher local development cess collection from polluting sectors (coal mining and coal-fired power generation) under the low-renewables scenario versus lower government spending to meet the health-care needs of locals (especially poor households) under the high-renewables scenario.
- Higher bailout packages to discoms every few years to offset their financial losses under the low-renewables scenario versus higher one-time stranded asset payments to close down expensive and inefficient coal-fired power plants under the high-renewables scenario.
- Higher royalty collections from coal mining by states under the low-renewables scenario versus lower subsidy rollout to meet the widening differences in electricity supply costs and tariffs under the high-renewables scenario.
- Higher recurring expenses on either (a) moving electricity from centrally situated power plants (closer to mines) or (b) moving fuel from mines to plants located near to load centres under the low-renewables scenario versus higher one-time expenses to locate solar projects much closer to load centres (and even opting for more distributed PV) under the high-renewables scenario.
- Long-term trade-offs with critical regional resources like water, land and air quality under the low-renewables scenario versus the possibility of a smaller power sector resource footprint with

better provisioning for land, water and clean air resources for local populations under the high-renewables scenario.

This work is a first-of-its-kind attempt to provide an integrated analysis of the implicit socioeconomic impacts inextricably linked with different transition trajectories of the Indian power sector at the state level. The analysis reveals strong evidence of an opportunity for regional economic growth and development associated with transitioning to a higher renewable trajectory and points to key trade-offs and possible future risks. Through this work, we hope to initiate and facilitate better informed and holistic deliberations among regional stakeholders about India's power sector transition.

# Annexure 1: Yearly domestic production and import of coal

| Year | Domestic production (million tonnes) | Imports (million tonnes) |
|---|---|---|
| FY03 | 341 | 23 |
| FY04 | 361 | 22 |
| FY05 | 383 | 29 |
| FY06 | 407 | 38 |
| FY07 | 431 | 43 |
| FY08 | 457 | 50 |
| FY09 | 493 | 59 |
| FY10 | 532 | 73 |
| FY11 | 532 | 69 |
| FY12 | 540 | 103 |
| FY13 | 556 | 110 |
| FY14 | 565 | 137 |
| FY15 | 609 | 186 |
| FY16 | 640 | 166 |
| FY17 | 673 | 146 |
| FY18 | 689 | 145 |
| FY19E | 748 | 165 |
| FY20E | 795 | 162 |

# Annexure 2: States and union territories of India

| State/Union Territory | State Code | | State/Union Territory | State Code |
|---|---|---|---|---|
| Andhra Pradesh | AD | | Meghalaya | ML |
| Arunachal Pradesh | AR | | Mizoram | MZ |
| Assam | AS | | Nagaland | NL |
| Bihar | BR | | Odisha | OD |
| Chhattisgarh | CG | | Pondicherry | PY |
| Delhi | DL | | Punjab | PB |
| Goa | GA | | Rajasthan | RJ |
| Gujarat | GJ | | Sikkim | SK |
| Haryana | HR | | Tamil Nadu | TN |
| Himachal Pradesh | HP | | Telangana | TL |
| Jammu and Kashmir | JK | | Tripura | TR |
| Jharkhand | JH | | Uttar Pradesh | UP |
| Karnataka | KA | | Uttarakhand | UK |
| Kerala | KL | | West Bengal | WB |
| Lakshadweep Islands | LD | | Andaman and Nicobar Islands | AN |
| Madhya Pradesh | MP | | Chandigarh | CH |
| Maharashtra | MH | | Dadra and Nagar Haveli | DN |
| Manipur | MN | | Daman and Diu | DD |


Jammu & Kashmir
Himanchal Pradesh
Punjab
Uttaranchal
Haryana
Delhi
Arunachal Pradesh
Sikkim
Rajasthan
Uttar Pradesh
Assam
Nagaland
Bihar
Meghalaya
Manipur
Jharkhand
Gujarat
Madhya Pradesh
West Bengal
Mizoram
Tripura
Chhattisgarh
Orrisa
Maharastra
Andhra Pradesh
Goa
Karnataka
Tamil Nadu
Pondicherry
Kelala

# Annexure 3: Model inputs

| Capacity (GW) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **State** | **Code** | **Coal** | | | **Solar** | | | **Wind** | | | **Others** | | |
| | | 2018 | 2030 (LR) | 2030 (HR) | 2018 | 2030 (LR) | 2030 (HR) | 2018 | 2030 (LR) | 2030 (HR) | 2018 | 2030 (LR) | 2030 (HR) |
| Andhra Pradesh and Telangana | AD&TL | 17.1 | 22.5 | 20.4 | 3.6 | 24.6 | 47.9 | 2.4 | 8.4 | 8.5 | 5.3 | 6.3 | 6.2 |
| Chhattisgarh | CG | 6.3 | 8.9 | 9.9 | 0.2 | 1.6 | 3.9 | 0.0 | 0.0 | 0.0 | 1.2 | 1.6 | 1.9 |
| Gujarat | GJ | 21.9 | 29.4 | 29.6 | 2.0 | 13.8 | 29.8 | 4.1 | 15.1 | 17.1 | 3.5 | 5.3 | 5.7 |
| Jharkhand | JH | 5.7 | 9.2 | 10.5 | 0.0 | 0.4 | 0.9 | 0.5 | 2.4 | 3.1 | 1.7 | 2.6 | 3.3 |
| Karnataka | KA | 9.9 | 12.5 | 11.0 | 2.5 | 16.6 | 31.6 | 3.9 | 13.3 | 13.1 | 6.1 | 8.4 | 8.4 |
| Madhya Pradesh | MP | 8.2 | 9.6 | 8.6 | 2.0 | 12.2 | 23.3 | 2.6 | 8.2 | 8.2 | 3.5 | 4.1 | 3.9 |
| Maharashtra | MH | 26.9 | 39.1 | 41.7 | 0.9 | 7.2 | 16.4 | 6.1 | 24.1 | 28.8 | 9.4 | 13.7 | 15.9 |
| Odisha | OR | 5.4 | 7.6 | 8.1 | 0.2 | 1.4 | 3.3 | 0.0 | 0.0 | 0.0 | 2.6 | 3.8 | 4.7 |
| Punjab | PB | 9.3 | 12.6 | 11.9 | 1.6 | 11.2 | 22.8 | 0.8 | 2.8 | 3.0 | 3.14 | 4.24 | 4.41 |
| Rajasthan | RJ | 11.7 | 13.5 | 11.6 | 3.6 | 22.0 | 40.1 | 4.4 | 13.7 | 13.0 | 4.8 | 5.8 | 5.3 |
| Tamil Nadu | TN | 12.5 | 15.5 | 14.4 | 2.6 | 16.7 | 33.2 | 7.5 | 25.3 | 26.3 | 6.1 | 9.1 | 8.9 |
| Uttar Pradesh | UP | 17.5 | 25.2 | 27.6 | 0.9 | 6.6 | 15.5 | 0.0 | 0.0 | 0.0 | 3.6 | 5.3 | 6.3 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| West Bengal | WB | 11.4 | 16.1 | 18.4 | 0.1 | 0.5 | 1.2 | 0.9 | 3.5 | 4.5 | 3.4 | 4.5 | 5.7 |
| Delhi | DL | 5.5 | 9.4 | 10.5 | 0.2 | 1.4 | 3.3 | 0.0 | 0.0 | 0.0 | 2.0 | 3.1 | 3.7 |
| National Total | NL | 190.0 | 262.3 | 266.7 | 21.8 | 147.5 | 297.7 | 34.3 | 121.2 | 130.6 | 74.0 | 107.5 | 117.7 |

| **Generation (TWh)** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **State** | **Code** | **Coal** | | | **Solar** | | | **Wind** | | | **Others** | | |
| | | 2018 | 2030 (LR) | 2030 (HR) | 2018 | 2030 (LR) | 2030 (HR) | 2018 | 2030 (LR) | 2030 (HR) | 2018 | 2030 (LR) | 2030 (HR) |
| Andhra Pradesh and Telangana | AD&TL | 89.9 | 143.7 | 107.4 | 6.0 | 41.3 | 80.7 | 5.3 | 19.1 | 19.4 | 21.3 | 32.6 | 36.4 |
| Chhattisgarh | CG | 33.3 | 56.6 | 52.2 | 0.4 | 2.7 | 6.5 | 0.0 | 0.0 | 0.0 | 4.4 | 6.4 | 7.4 |
| Gujarat | GJ | 115.0 | 188.0 | 155.8 | 3.8 | 26.5 | 57.5 | 10.1 | 37.0 | 41.7 | 14.8 | 27.1 | 28.8 |
| Jharkhand | JH | 29.8 | 59.0 | 55.2 | 0.1 | 0.6 | 1.5 | 1.0 | 4.2 | 5.4 | 6.3 | 10.1 | 12.3 |
| Karnataka | KA | 52.3 | 79.8 | 58.1 | 4.4 | 28.9 | 54.8 | 8.9 | 30.3 | 29.9 | 23.2 | 39.5 | 40.6 |
| Madhya Pradesh | MP | 43.2 | 61.5 | 45.0 | 3.3 | 20.5 | 39.0 | 5.2 | 16.4 | 16.3 | 14.7 | 22.4 | 23.4 |
| Maharashtra | MH | 141.3 | 250.0 | 219.6 | 1.6 | 12.2 | 27.9 | 13.9 | 55.0 | 65.7 | 37.9 | 62.2 | 69.7 |
| Odisha | OR | 28.4 | 48.5 | 42.8 | 0.3 | 2.3 | 5.3 | 0.0 | 0.0 | 0.0 | 8.7 | 12.7 | 15.3 |
| Punjab | PB | 48.7 | 80.4 | 62.6 | 2.5 | 17.9 | 36.4 | 1.3 | 4.9 | 5.2 | 12.7 | 21.0 | 23.8 |
| Rajasthan | RJ | 61.8 | 86.5 | 60.9 | 6.3 | 38.3 | 69.9 | 9.0 | 28.1 | 26.8 | 22.6 | 36.0 | 35.7 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tamil Nadu | TN | 65.8 | 99.3 | 75.6 | 4.3 | 28.2 | 56.1 | 20.1 | 67.8 | 70.2 | 29.9 | 53.6 | 53.2 |
| Uttar Pradesh | UP | 92.3 | 161.4 | 145.2 | 1.4 | 10.5 | 24.7 | 0.0 | 0.0 | 0.0 | 13.5 | 22.6 | 26.6 |
| West Bengal | WB | 59.9 | 103.0 | 96.6 | 0.1 | 0.8 | 1.9 | 2.0 | 7.7 | 9.8 | 12.5 | 17.0 | 20.4 |
| Delhi | DL | 29.0 | 60.0 | 55.2 | 0.2 | 1.9 | 4.6 | 0.0 | 0.0 | 0.0 | 9.6 | 16.2 | 18.7 |
| National Total | NL | 999.5 | 1678.5 | 1402.9 | 37.0 | 250.4 | 505.1 | 78.8 | 278.0 | 299.3 | 296.3 | 492.9 | 540.4 |

# Annexure 4: About the E3-India model

Regulatory Assistance Project (RAP), in collaboration with Cambridge Econometrics (CE), UK, has developed the first ever state-level macroeconometric model for evidence-based policy making in India: E3-India. Developed with transparency and ease of access in mind, the model is designed to vastly improve the ability of users to develop a shared and collective understanding of various energy issues, thereby creating space for consensus building around key policy interventions. Our team successfully delivered the initial version of E3-India to the public domain in mid-2017 and is working towards release of the next version, scheduled to be released in August 2019. This work has been performed using the beta version.

The core motivation behind development of E3-India is to enable both policymakers and stakeholders to assess the policy impact of clean energy investments at a significantly higher geographic resolution. Currently, the primary geographical unit of such analyses in India is restricted to national-level studies. Higher geographic resolution will require engagement of a far larger group of policymakers and stakeholders. A sophisticated evaluation framework like E3-India can then act as a tool to expedite positive outcomes towards cleaner transitions.

## Model details

E3-India is a macroeconometric simulation, featuring a unique demand-driven, disequilibrium framework. The model combines a standard system of national/state accounts (IOTs), with a series of econometric equations to capture the behavioural relationships and responses of the economy to policy. The model provides an integrated treatment of India's state economies, energy systems and emissions, enabling the model to capture two-way linkages and the feedback between these components. It also features a unique Future Technology Transfer (FTT) module for evaluation of transitions in the energy sector. Unlike the more common computable general equilibrium (CGE) approach to economic modelling, E3-India does not assume full employment or perfectly competitive markets; instead, it estimates behaviour based on available historical data.

Compared to other macroeconomic models in operation currently across the world, E3-India has advantages in four important areas:

- Geographical coverage, with explicit representation of each state and territory in India.
- Sectoral disaggregation — which allows for the representation of fairly complex scenarios at the state level and the ability to ascertain the impact of any policy measure — can be represented in a detailed way to show winners and losers.
- The econometric pedigree and empirical grounding of the model makes it better able to represent performance in the short to medium term, as well as providing long-term assessments without being too reliant on rigid assumptions.
- E3 linkages and the hybrid nature of the model: a nonlinear interaction among the economy, energy demand/supply and environmental emissions is an undoubtable advantage over other models.

The model enables users to estimate a wide range of socioeconomic outputs at the state and national level, for example:

- Employment and unemployment.
- GDP and sectoral output.
- Investment, international trade and trade among states.
- Household income (by income group) and consumption.
- Public balances, prices and inflation.

## Modelling framework

The effects of economic interactions among individuals, households, firms and other economic agents are visible after a time lag, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors, and the effects, both positive and negative, accumulate in economic and physical stocks. The effects are transmitted through the environment (for example, through greenhouse gas emissions contributing to global warming), through the economy and the price and money system (via the markets for labour and commodities) and through transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through income spent on goods and services. These interdependencies suggest that an E3 model should be comprehensive (i.e., covering the whole economy) and include a full set of linkages among different parts of the economic and energy systems.

The economic and energy systems have the following characteristics:

- Economies and diseconomies of scale in both production and consumption.
- Markets with different degrees of competition.
- The prevalence of institutional behaviour whose aim may be maximisation but may also be the satisfaction of more restricted objectives.
- Rapid and uneven changes in technology and consumer preferences, certainly within the time scale of greenhouse gas mitigation policy.

Labour markets in particular may be characterised by long-term unemployment. An E3 model capable of representing these features must therefore be flexible and capable of embodying a variety of behaviours and of simulating a dynamic system. This approach can be contrasted with that adopted by general equilibrium models as they typically assume:

- Constant returns to scale.
- Perfect competition in all markets.
- Maximisation of social welfare measured by total discounted private consumption.
- No involuntary unemployment.
- Exogenous technical progress following a constant time trend.[78]

78 For a more detailed discussion, see Barker, T. S. (1998). Use of energy-environment-economy models to inform greenhouse gas mitigation policy. *Impact Assessment and Project Appraisal, 16*(2), 123-131.

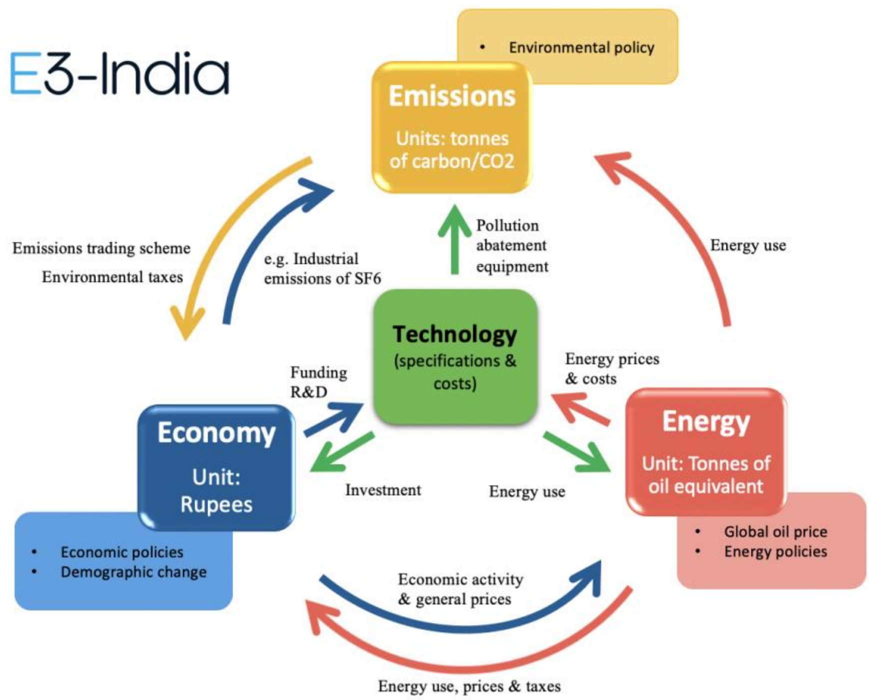
## Basic model structure

The E3-India model comprises:

- The accounting framework of the economy, coupled with balances for energy demands and environmental emission flows.
- Detailed historical data sets, with time series covering the period since 1993, and sectoral disaggregation.
- An econometric specification of behavioural relationships in which short-term deviations move towards long-term trends.
- The software to hold together these other component parts.

Figure A1 shows how the three components (modules) of the model (energy, environment and economy) fit together.

**Figure A1. E3-India: Economy-energy-environment linkages**




Source: Pollit, H. (2017). *Introduction to the E3-India macroeconomic model*.

## Module description

Each component is shown in its own box with its own units of account and sources of data. Each data set has been constructed to conform to accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For the economic module, these include demographic factors and economic policy (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of energy industries). For the environmental component, exogenous factors include policies such as carbon taxes. The linkages among the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

The economy module provides measures of economic activity and general price levels to the energy module; the energy module then determines levels and prices of energy consumption, which is passed to the emissions module and is also fed back to the economic module.

## The Future Technology Transfer (FTT) module

Power is a bottom-up model of technology diffusion across 24 power sector technologies. The model was originally built by Dr. Jean-Francois Mercure in Cambridge and is a core feature in Cambridge Econometrics' macroeconomic models. The model provides a framework for the dynamic selection and diffusion of innovations, which in E3-India is applied to the power sector in each Indian state. It is based on two key curves: the S-shaped curve of technology diffusion and the logistic curve of reduced production costs due to learning.

The power sector is represented using a novel framework for the dynamic selection and diffusion of innovations called FTT: Power (Future Technology Transformations in the Power sector).[79] This is the first member of the FTT family of technology diffusion models. FTT uses a decision-making core for investors wanting to build new electrical capacity, facing several options. The resulting diffusion of competing technologies is constrained by a global database of renewable and nonrenewable resources. The decision-making core takes place by pairwise levelised cost of energy (LCOE) comparisons, conceptually equivalent to a binary logit model, parameterised by measured technology cost distributions. Costs include reductions originating from learning curves, as well as increasing marginal costs of renewable natural resources (for renewable technologies) using cost-supply curves. The diffusion of technology follows a set of coupled nonlinear differential equations, sometimes called Lotka-Volterra or replicator dynamics, which represent the better ability of larger or well-established industries to capture the market and the life expectancy of technologies. Due to learning by doing and increasing returns to adoption, it results in path-dependent technology scenarios that arise from electricity sector policies.

## The representation of FTT

Power in the global E3ME model includes constraints on the supply of both renewable and nonrenewable [80] resources (e.g., barrels of oil or suitable sites for wind farms).[81]

The supply of nonrenewable resources is treated as exogenous in E3-India, since the rest of the world is not included. The working assumption is that India can continue to produce coal with extraction costs similar to the current ones (allowing for inflation) over the period to 2035. Due to data restrictions, it is only possible to introduce state-level constraints for some renewable technologies:

79 Mercure, J-F., & Salas, P. (2012). An assessment of global energy resource economic potentials. *Energy, 46*(1), 322–336. https://www.researchgate.net/publication/225027613_An_assessement_of_global_energy_resource_economic_potentials

80 Mercure, J-F, and P Salas (2013), On the global economic potentials and marginal costs of non-renewable resources and the price of energy commodities. *Energy Policy, 63*, 469–483.

81 Mercure & Salas, 2012.

- For wind and solar, using information from MapRE,[82] we introduce cost curves to include diminishing capacity factors.
- For hydro, state-level maximum potentials are added using information from Energy Alternative India (EAI).[83]
- Landlocked states have zero potentials for wave, tidal and offshore wind.

## Model specifications

E3-India is developed as an advanced software tool to assess energy-economy linkages in Indian states and captures:

- 32 Indian states and territories.
- 39 economic sectors, 12 urban, 12 rural income quintiles.
- 21 users of five different energy carriers.
- Annual projections out to 2035.

The latest version of the model is due to be released in August 2019, and a beta version has been used in this analysis to provide insights with respect to indirect impacts of energy transitions.

82 Mercure & Salas, 2012.

83 EAI Consulting. (2017). India hydro energy. http://www.eai.in/ref/ae/hyd/hyd.html

# Model parameters

| 32 regions | |
|---|---|
| 1 Andhra Pradesh (AD)* | 17 Meghalaya (ML) |
| 2 Arunachal Pradesh (AR) | 18 Mizoram (MZ) |
| 3 Assam (AS) | 19 Nagaland (NL) |
| 4 Bihar (BR) | 20 Odisha (OD) |
| 5 Chhattisgarh (CG) | 21 Punjab (PB) |
| 6 Gujarat (GJ) | 22 Rajasthan (RJ) |
| 7 Haryana (HR) | 23 Sikkim (SK) |
| 8 Himachal Pradesh (HP) | 24 Tamil Nadu (TN) |
| 9 Goa (GA) | 25 Tripura (TR) |
| 10 Jammu and Kashmir (JK) | 26 Uttar Pradesh (UP) |
| 11 Jharkhand (JH) | 27 Uttarakhand (UK) |
| 12 Karnataka (KA) | 28 West Bengal (WB) |
| 13 Kerala (KL) | 29 Andaman and Nicobar (AN) |
| 14 Madhya Pradesh (MP) | 30 Chandigarh (CH) |
| 15 Maharashtra (MH) | 31 Delhi (DL) |
| 16 Manipur (MN) | 32 Pondicherry (PY) |

*

* Andhra Pradesh and Telangana are treated together in E3-India as Telangana is a new state formed out of Andhra Pradesh in 2014 and historic data for the modelling was not available separately for the state.

| 24 power sector technologies | |
|---|---|
| 1 Nuclear | 13 Biogas |
| 2 Oil | 14 Biogas + CCS |
| 3 Coal | 15 Tidal |
| 4 Coal + CCS | 16 Large hydro |
| 5 IGCC | 17 On shore |
| 6 IGCC + CCS | 18 Off shore |
| 7 CCGT | 19 Solar PV |
| 8 CCGT + CCS | 20 CSP |
| 9 Solid biomass | 21 Geothermal |
| 10 S biomass CCS | 22 Wave |
| 11 BIGCC | 23 Fuel cells |
| 12 BIGCC + CCS | 24 CHP |

| **39 sectors** | | |
|---|---|---|
| 1 Agriculture, etc. | 14 Rubber, plastics | 27 Trade, logistics |
| 2 Forestry | 15 Non-metal/mineral products | 28 Hotels, catering |
| 3 Coal | 16 Basic metals | 29 Land transport, etc. |
| 4 Oil, gas, etc. | 17 Metal goods | 30 Water transport |
| 5 Other mining | 18 Electronics | 31 Air transport |
| 6 Food, drink, tobacco | 19 Electrical engineering, instruments | 32 Communications |
| 7 Textiles, clothing | 20 Motor vehicles | 33 Banking, insurance |
| 8 Leather | 21 Other transport equipment | 34 Other business services |
| 9 Wood | 22 Other manufacturing | 35 Public administration, defence |
| 10 Paper, printing, publishing | 23 Electricity supply | 36 Education |
| 11 Manufacturing fuels | 24 Gas supply | 37 Health care, social work |
| 12 Pharmaceuticals | 25 Water supply | 38 Miscellaneous services |
| 13 Chemicals | 26 Construction | 39 Unallocated |

| Consumers expenditure |
|---|
| 1 Food |
| 2 Drink |
| 3 Tobacco |
| 4 Clothing, etc. |
| 5 Rent |
| 6 Water, etc. |
| 7 Electricity |
| 8 Gas |
| 9 Liquid fuels |
| 10 Other fuels |
| 11 Durable goods |
| 12 Other consumables |
| 13 Medical |
| 14 Transport services |
| 15 Other services |
| 16 Recreational |
| 17 Unallocated |

| 24 household income categories | |
|---|---|
| 1 Rural (0-5) | 13 Urban (0-5) |
| 2 Rural (5-10) | 14 Urban (5-10) |
| 3 Rural (10-20) | 15 Urban (10-20) |
| 4 Rural (20-30) | 16 Urban (20-30) |
| 5 Rural (30-40) | 17 Urban (30-40) |
| 6 Rural (40-50) | 18 Urban (40-50) |
| 7 Rural (50-60) | 19 Urban (50-60) |
| 8 Rural (60-70) | 20 Urban (60-70) |
| 9 Rural (70-80) | 21 Urban (70-80) |
| 10 Rural (80-90) | 22 Urban (80-90) |
| 11 Rural (90-95) | 23 Urban (90-95) |
| 12 Rural (95-100) | 24 Urban (95-100) |

| 5 government sectors |
|---|
| 1 Defence |
| 2 Education |
| 3 Health |
| 4 Other |
| 5 Unallocated |

| Labour groups |
|---|
| 1 Male 15-19 |
| 2 Male 20-24 |
| 3 Male 25-29 |
| 4 Male 30-34 |
| 5 Male 35-39 |
| 6 Male 40-44 |
| 7 Male 44-49 |
| 8 Male 50-54 |
| 9 Male 55-59 |
| 10 Male 60-64 |
| 11 Male 65+ |
| 12 Female 15-19 |
| 13 Female 20-24 |
| 14 Female 25-29 |
| 15 Female 30-34 |
| 16 Female 35-39 |
| 17 Female 40-44 |
| 18 Female 45-49 |
| 19 Female 50-54 |
| 20 Female 55-59 |
| 21 Female 60-64 |
| 22 Female 65+ |
| 23 Total 15-19 |
| 24 Total 20-24 |
| 25 Total 25-29 |
| 26 Total 30-34 |
| 27 Total 35-39 |
| 28 Total 40-44 |
| 29 Total 45-49 |
| 30 Total 50-54 |
| 31 Total 55-59 |
| 32 Total 60-64 |
| 33 Total 65+ |

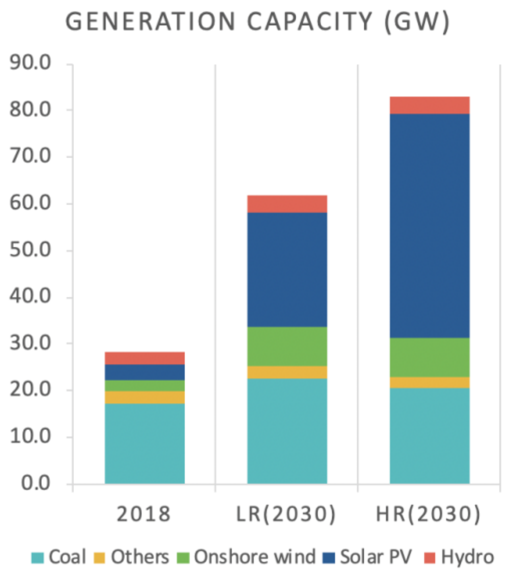
| Population groups |
|---|
| 1 Male Children |
| 2 Male 15-19 |
| 3 Male 20-24 |
| 4 Male 25-29 |
| 5 Male 30-34 |
| 6 Male 35-39 |
| 7 Male 40-44 |
| 8 Male 44-49 |
| 9 Male 50-54 |
| 10 Male 55-59 |
| 11 Male 60-64 |
| 12 Male OAPs |
| 13 Female Children |
| 14 Female 15-19 |
| 15 Female 20-24 |
| 16 Female 25-29 |
| 17 Female 30-34 |
| 18 Female 35-39 |
| 19 Female 40-44 |
| 20 Female 45-49 |
| 21 Female 50-54 |
| 22 Female 55-59 |
| 23 Female 60-64 |
| 24 Female OAPs |

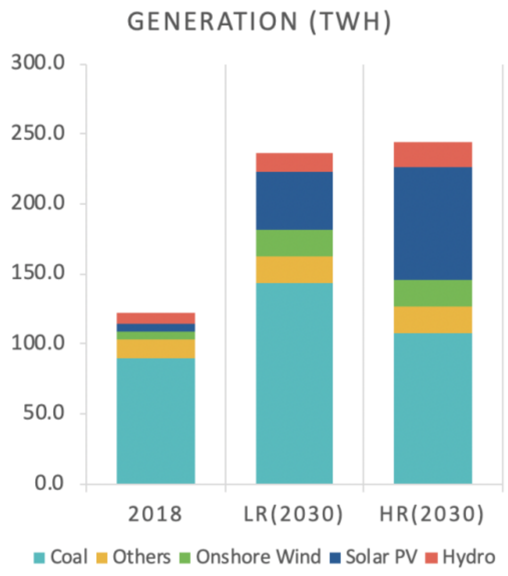
More details of the modelling framework are available at www.e3indiamodel.com.

Contact sjoshi@raponline.org to request the model manual and access to the beta version of E3-India (2019).

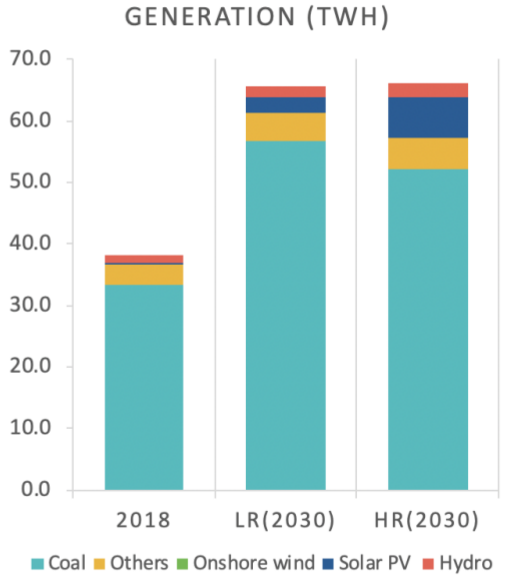
# Annexure 5: State Inputs

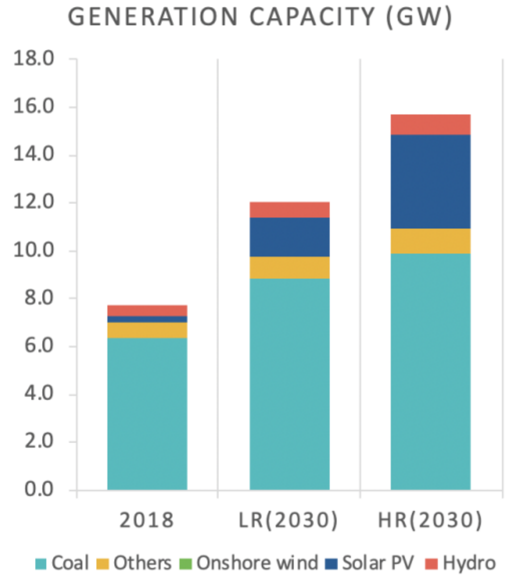
## Andhra Pradesh




## Chhattisgarh



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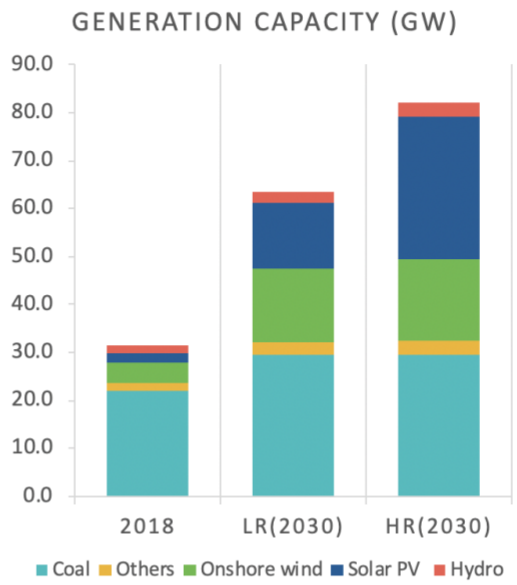


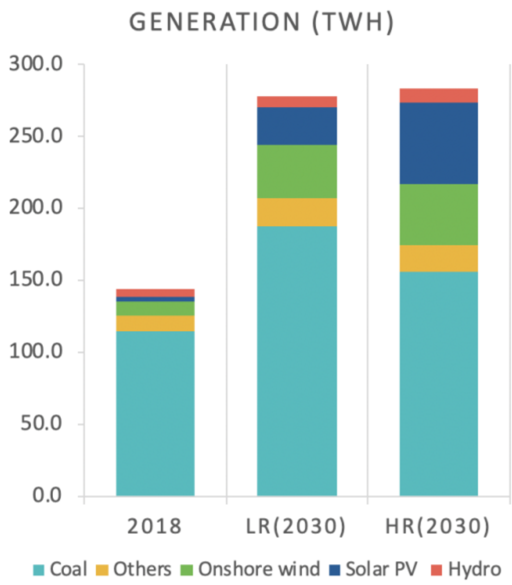


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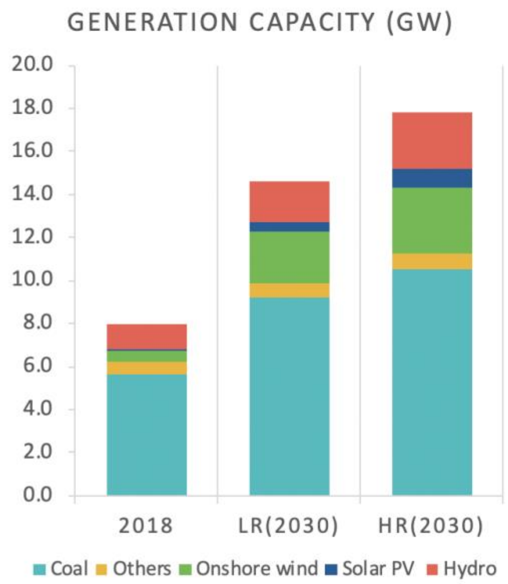


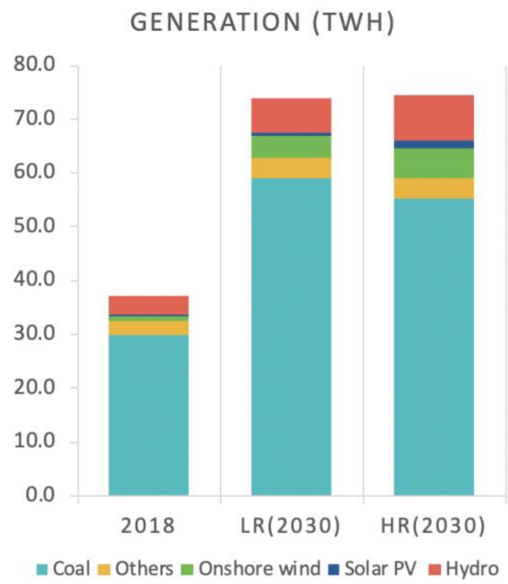

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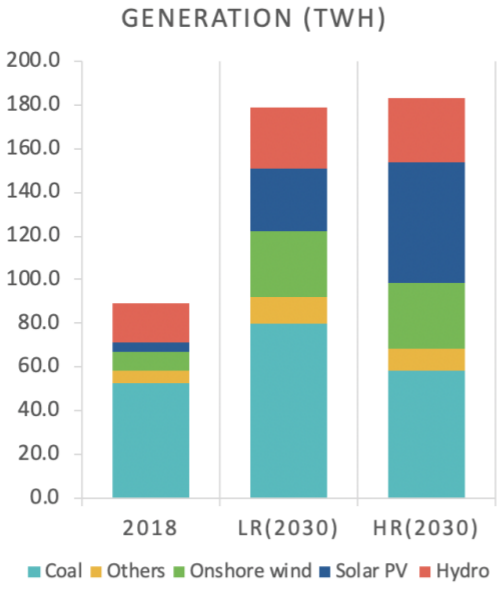


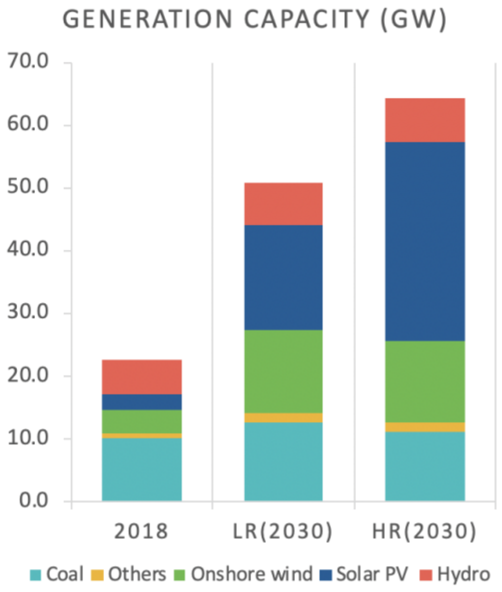


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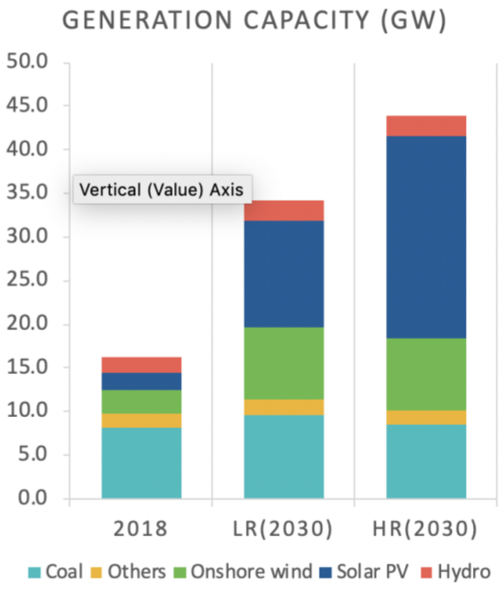


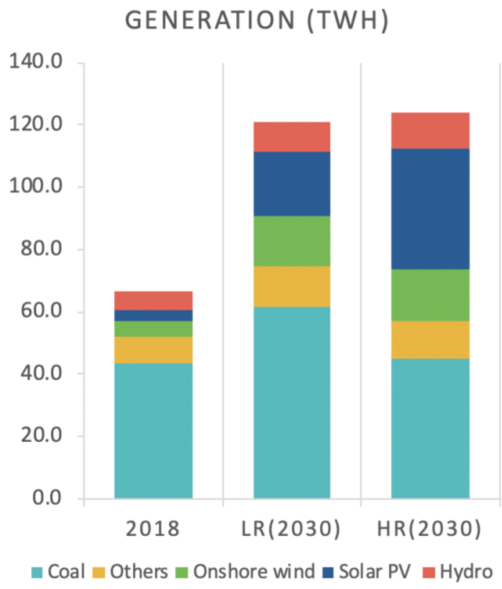

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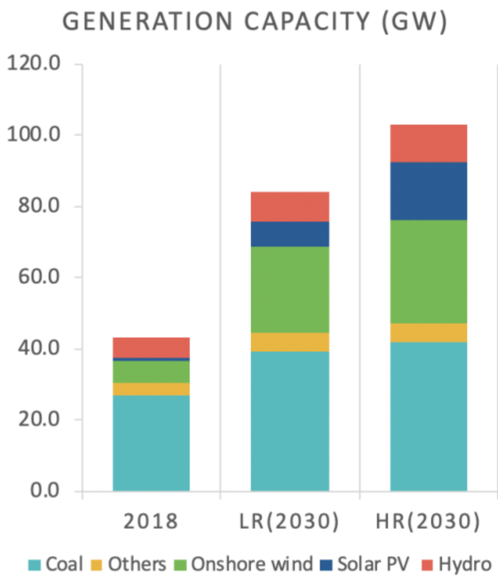


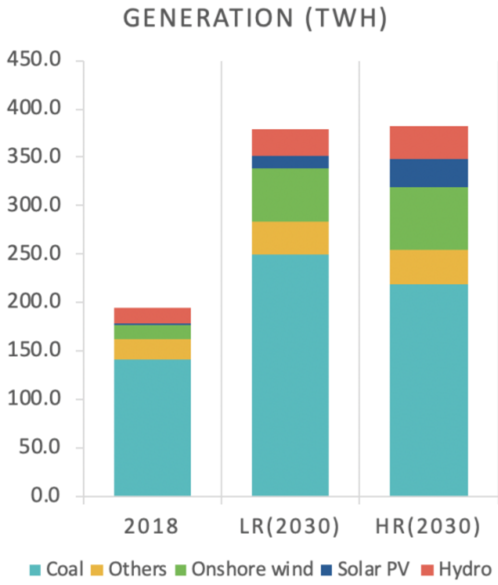


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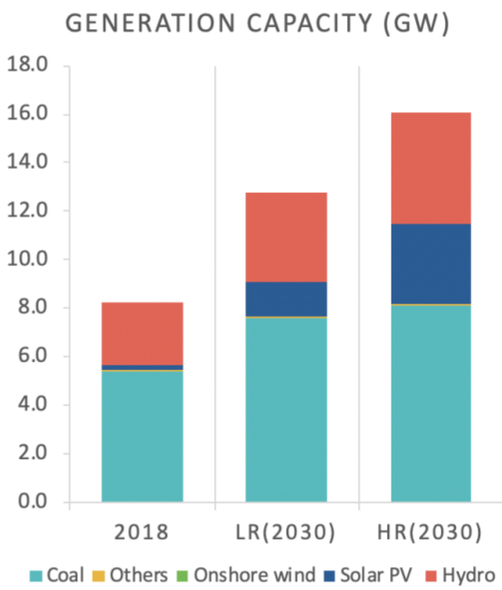


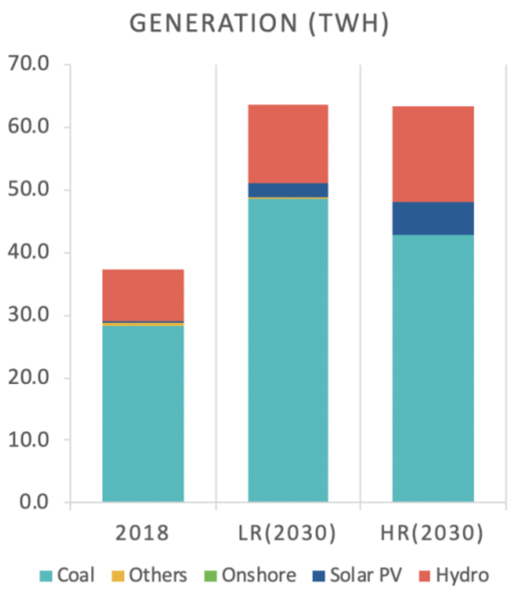

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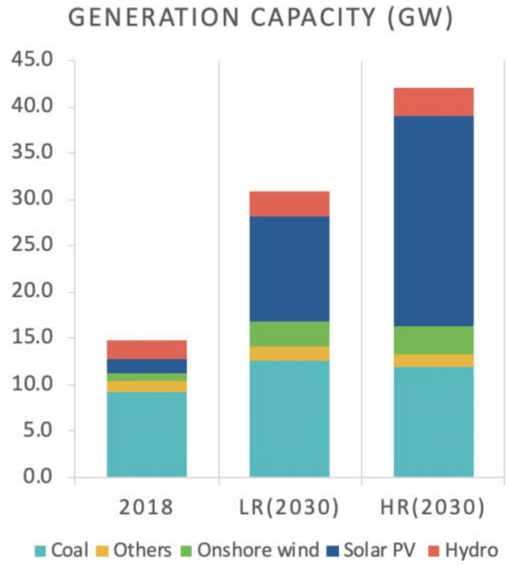


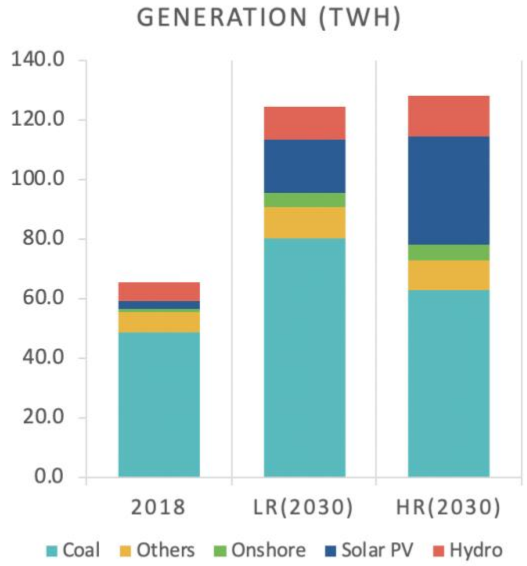


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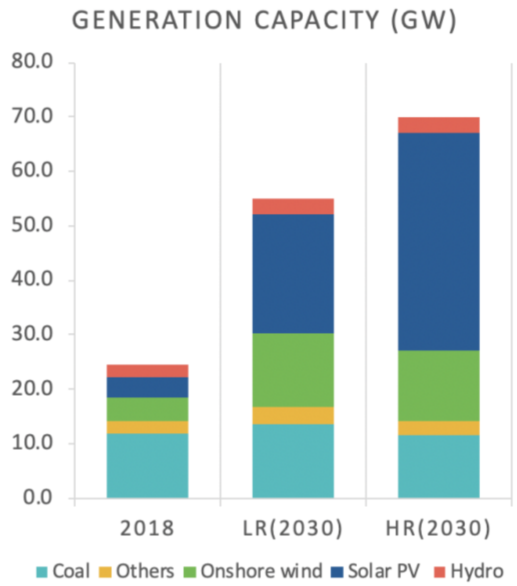


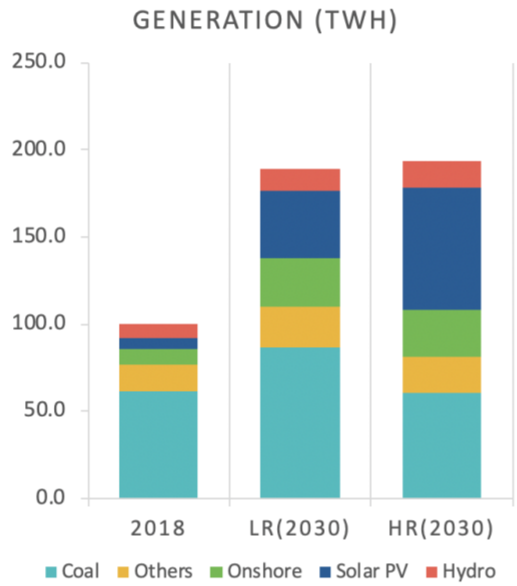

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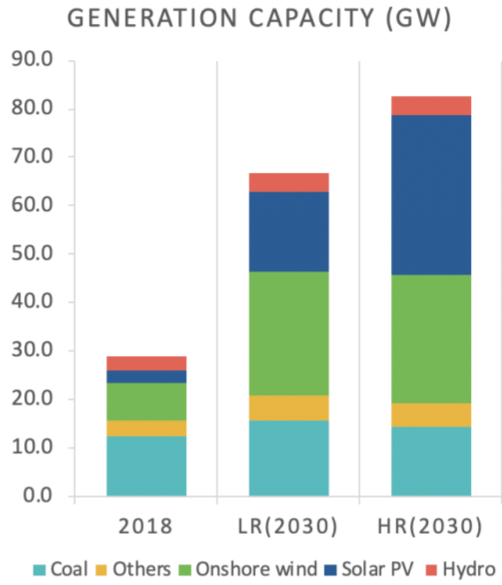


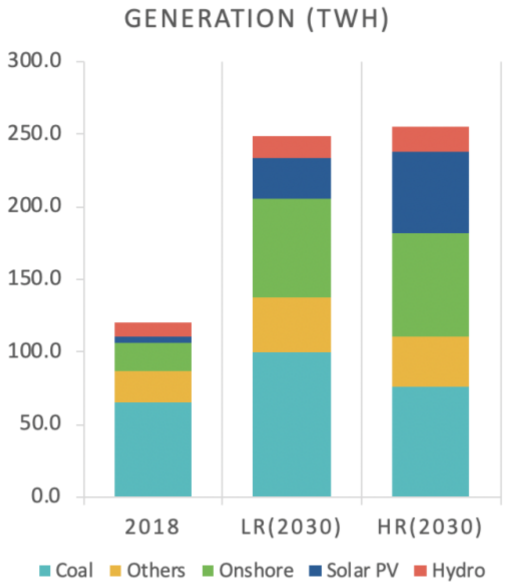




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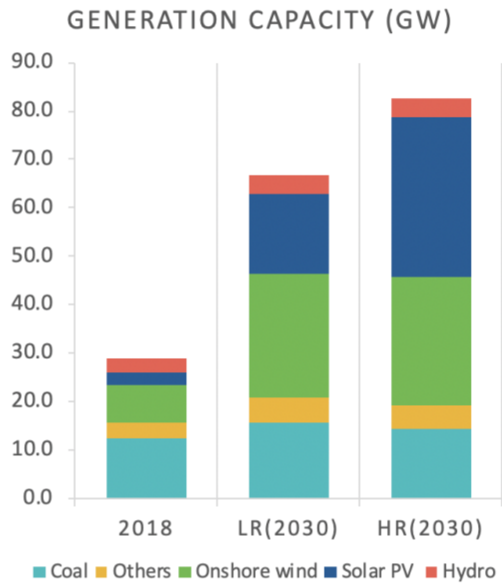


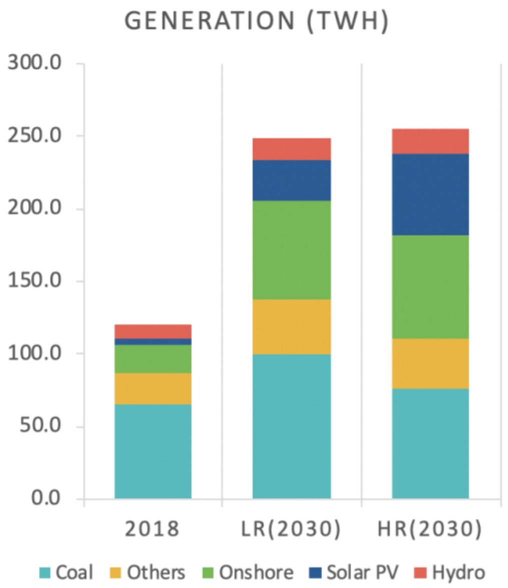

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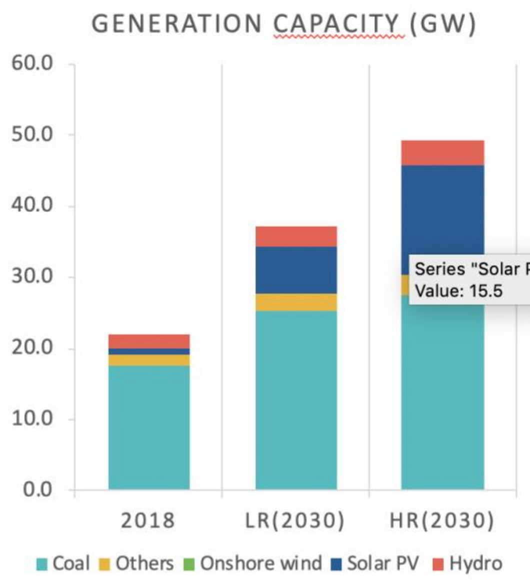
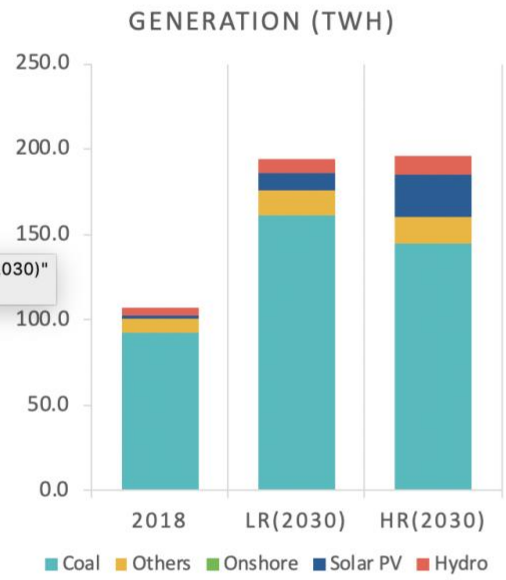
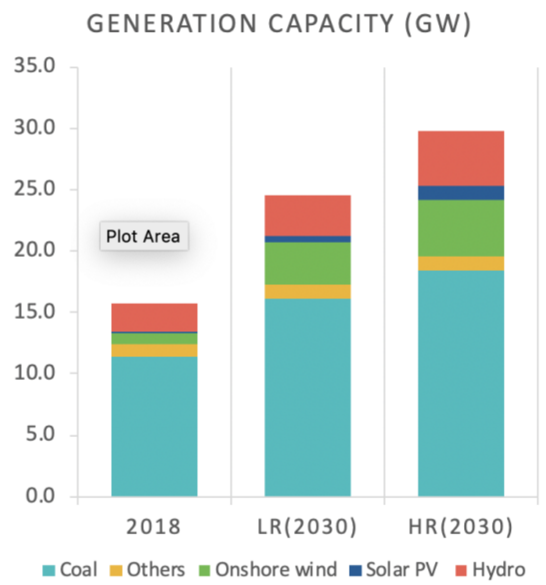
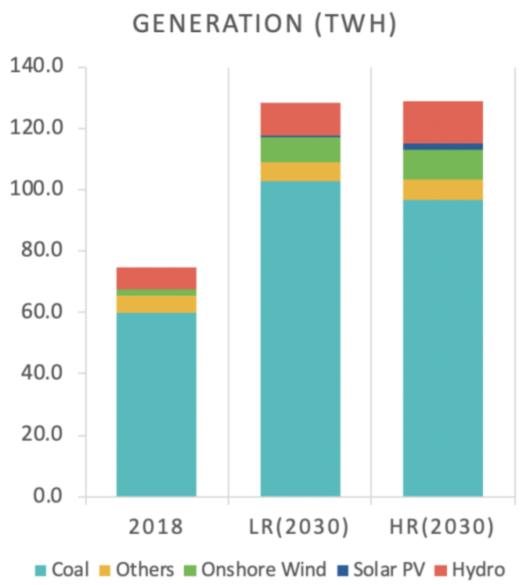



# West Bengal



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