BROOKINGS

Coal in India

Adjusting to transition

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PAPER 7
MARCH 2019

ACKNOWLEDGEMENTS

We are grateful for the generous support of the David M. Rubenstein Special Initiative Fund for enabling this joint effort between the Brookings Institution and Brookings India. This report builds on existing Brookings India research on the future of Indian coal—a study supported by a grant from Tata Steel. We also thank researchers at Brookings India for their help in data gathering and analysis, including Abhishek Mishra, Puneet Kamboj, Anurag Sehgal, Sahil Ali, and Tanmay Verma, and editorial help from Sydney Bartone, Rohan Laik, and Zehra Kazmi. We also thank participants at an author workshop at Brookings, and anonymous reviewers. We also acknowledge helpful comments and inputs from David G. Victor and Rohit Chandra.

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EXECUTIVE SUMMARY

Coal provides about half of India's commercial primary energy supply today and is the dominant fuel for power production in India. In 2014, Prime Minister Narendra Modi established ambitious goals for renewable energy (RE) development, aiming to quadruple its capacity by 2022. Despite expected growth in RE, we project that coal will remain the dominant fuel for electricity generation in India through 2030 and beyond, even though its share of generation will fall.[1] Although coal will continue to dominate power supply, the coal industry in India faces significant challenges and upcoming change.

Coal India Limited (CIL) is the world's largest coal mining company and produces 84 percent of India's thermal coal.[2] Most coal is sold to power producers, predominantly under fuel supply agreements, at administered prices. But, for years, CIL has not kept up with growing demand. The Indian government now allows end-users to produce their own coal and is moving toward allowing more private-sector mining. However, these changes do not address the underlying challenges of increasing domestic coal production—primarily, obtaining the necessary land and permits to expand production. India also imports coal, which is particularly used in coastal areas far from the coal mines of India's east.

The coal industry is knit into the fabric of the Indian economy. The central government owns a little over 75 percent of CIL,[3] which provides significant revenue to the national treasury through dividend payments. CIL is also a major employer, and, in many parts of India, the largest one. Levies on coal are an important source of revenue for the central government and especially for coal-producing states, among the poorest in the nation. Finally, Indian Railways' freight charges for coal subsidize passenger transport, and coal provides 44 percent of freight revenues, despite being only 40 percent of total freight tonne-kilometers.[4] For power plants located far from mines, transport can be the largest component of the delivered coal price.

In the last few years, India has moved from chronic power shortfalls to a situation of near surplus in power generation capacity. Growth in coal-fired power generation capacity has outstripped demand growth over the last several years. At the same time, the growing supply of RE is beginning to displace coal-fired generation in an opportunistic manner (when it is available), decreasing the load factors of some coal-fired plants and therefore decreasing their profitability. Coal plants already make up a significant category of financially distressed assets for the Indian banking sector. The most competitive coal plants in the future will be newer, more efficient plants, and those that can efficiently decrease production to accommodate variable RE generation. Plants located close to mines also have a clear advantage with respect to coal transportation costs. Older plants that require extensive upgrades to meet environmental rules or rules requiring generation flexibility will be less competitive.

India needs both coal and RE to meet its growing power needs, but the structure of the Indian power industry raises challenges for the complementary growth of these two technologies. State-level power distribution companies (DisComs) generally buy power from generators through power purchase agreements (PPAs)—static and rigid contracts that treat all power the same, regardless of whether it is intermittent or dispatchable, or by the time of day of availability. Competitive power markets with market-based fuel prices and time-of-day wholesale prices would send the right signals for developing new power sources, unlike the rigid PPAs in place today. However, the DisComs are nearly bankrupt, and, on average, lose money on every kilowatt-hour (kWh) sold, complicating the establishment of a competitive market. "Fixing" India's coal system is nearly impossible without addressing distortions across the entire value chain that spans coal mining, railways, power generators, and DisComs. Distortions also exist at the retail level, where commercial and industrial customers pay higher rates to subsidize other electricity consumers. Customers paying higher rates are those most likely to shift to RE self-generation, robbing the DisComs of their best customers.

Coal faces headwinds globally and there are two main types of opposition to coal. First is the concern over coal's externalities, both local pollution and greenhouse gas emissions with global consequences. Second is the belief that India doesn't need as much coal, as renewables now provide a cheaper alternative, and coal represents a risky and expensive investment.

Both forms of opposition rely on renewable energy as the alternative, but there are subtle differences. For the latter, the alternative just happens to be renewables; it could be any cheaper and available source. For example, natural gas is displacing coal in the United States. For the former, the framing is that is a country should be willing to pay more for cleaner power. If decisionmakers properly priced externalities, then the economics would favor alternatives to coal. However, in India, like in many emerging economies, development needs have often been paramount over environmental concerns.

Although coal use is growing, India is on track to meet its commitments under the Paris Agreement. Nonetheless, high RE targets have a lower impact on emissions than capacity numbers suggest, because baseload coal operates at about three times the capacity utilization of RE. Achieving deep decarbonization of India's energy mix will take time, and may require a combination of storage technologies, a more flexible and smarter grid, and efforts beyond the electricity sector.

In the meantime, India is focused on bringing electricity to 100 percent of homes, providing affordable power, and making utilities financially viable. The environment is also important, but climate change is not the main driver. Local air pollution is a more urgent issue, and upcoming stringent environmental norms may force some older and dirtier plants to shut down. Despite RE's visibility and ascent, cleaning up coal, including through more efficient plants, is a more realistic goal than wishing it away.

COAL IN INDIA

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Introduction: Coal in context in India

Coal is the source of half of commercial primary energy in India.[5] However, non-commercial biomass is still an important energy source, making up roughly one-quarter of total primary energy. The power sector uses the majority of India's coal (Figure 1) and coal dominates supply in the sector, in both capacity and generation terms (Figure 2 and Figure 3).

India primarily uses domestic coal, but also imports roughly 200 million tonnes of coal annually, including coking coal used in steel plants.[6] Power plants are designed to operate on coal of a specific quality—small deviations may lower efficiency while larger differences may not allow operations. Many plants in coastal areas far from coal mines are designed to run on imported coal. Imports are also blended with domestic coal to improve the average heat value—Indian coal generally has a high ash content and low heat value.

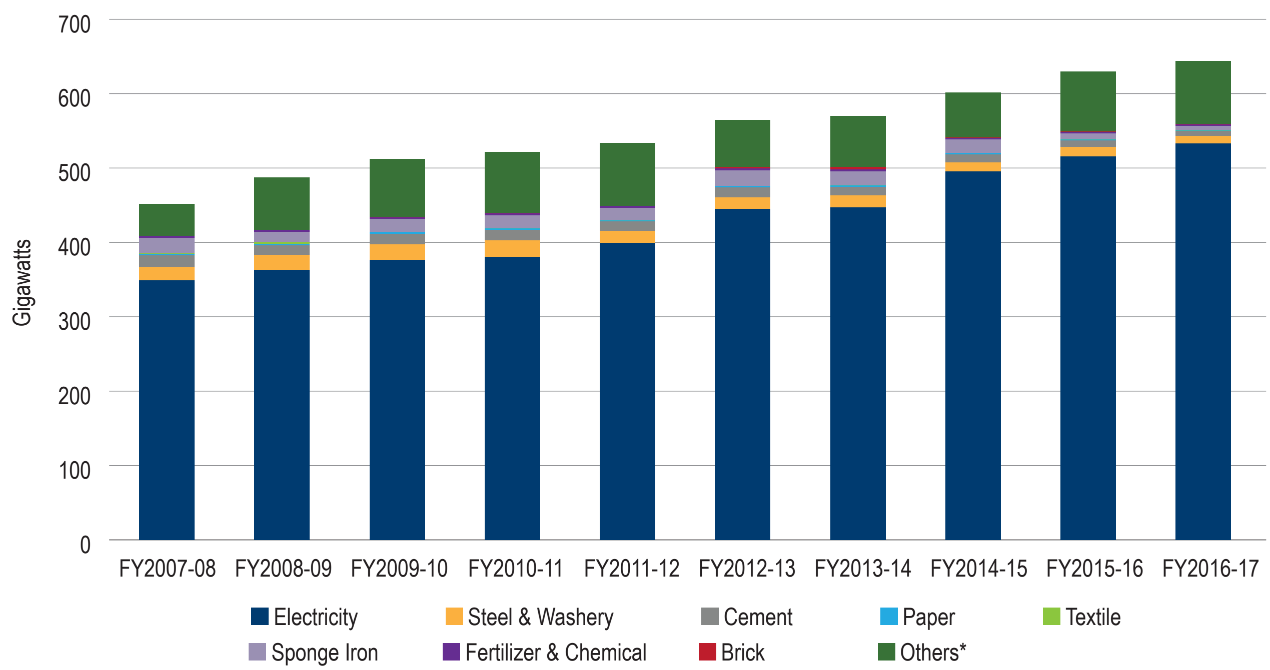
Structure of the coal ecosystem

Structure of India's electricity sector

Electricity is the primary user of coal, and the structure, regulation, and prospects for India's electricity sector are key to the future of coal in India. India's electricity sector has a mix of public and private ownership. Generation opened to the private sector in 1991, but reforms accelerated after 1998, when states began to unbundle their State Electricity Boards into separate generation, transmission, and distribution companies (DisComs). Most of these entities remain public-sector enterprises.

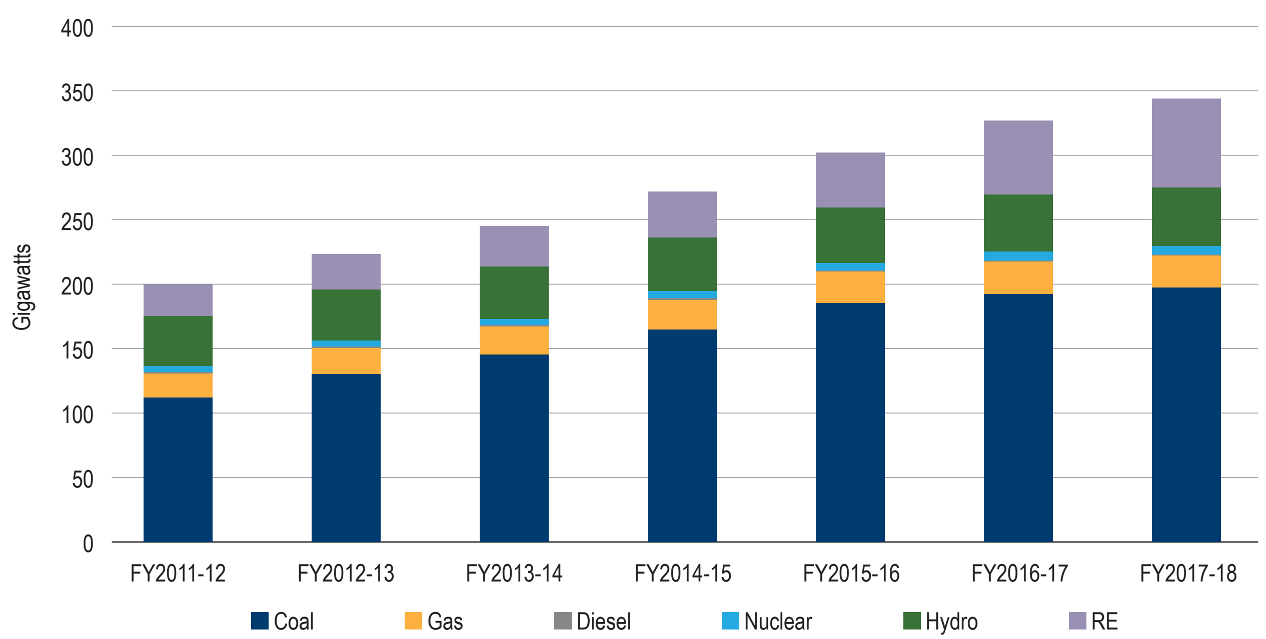
DisComs purchase power from a mix of publicly owned and private generators for sale to final consumers. However, the DisComs are in dire financial condition despite enormous subsidies paid by the state governments and periodic bailouts. Retail tariffs, set by ostensibly independent State Electricity Regulatory Commissions, are insufficient to meet the DisComs' costs and they lose just over 0.80 rupees per kilowatt-hour sold.[7] As of 2017, the DisComs also lost an average of 23 percent of their power to technical and "commercial" losses (theft

Figure 1: Coal consumption in India by sector



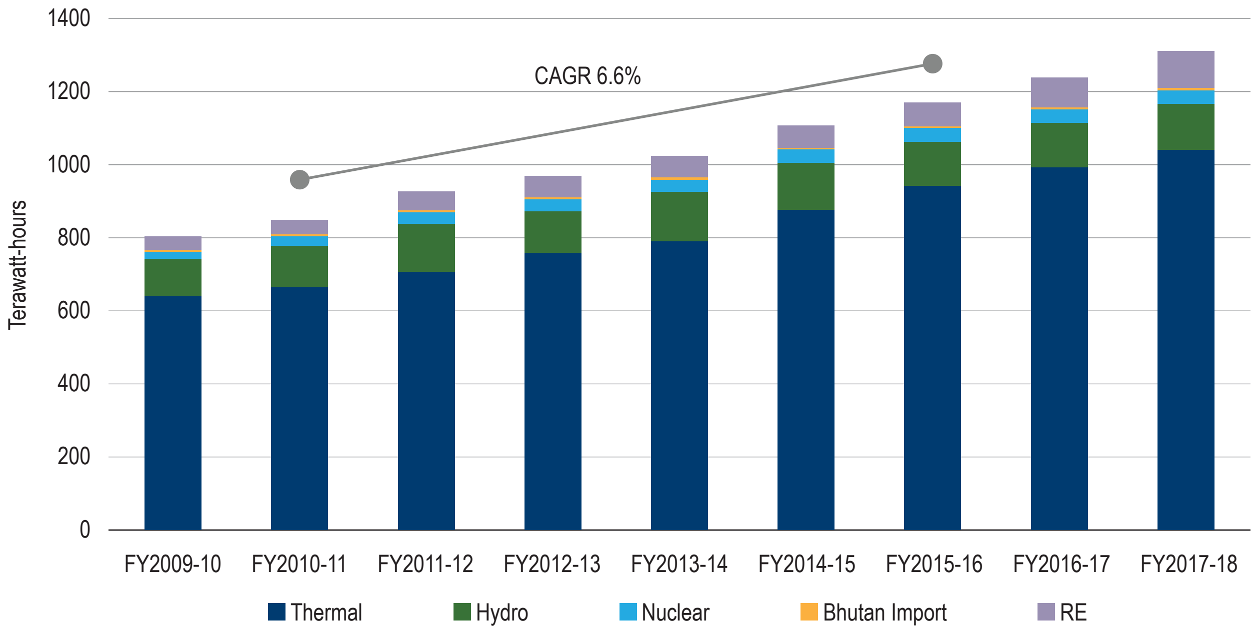
* The "Others" category includes colliery consumption, jute, coal for soft coke, colliery fertilizers (Until 2019-10, other also included bricks).
Source: Ministry of Coal Annual Reports.

Figure 2: India's gross electricity capacity by type



India does not classify large hydroelectric power (hydro) as RE. RE includes wind, solar, biomass, and mini-hydro.
Source: Central Electricity Authority (CEA) March Monthly Reports Executive Summaries, 2012-18.

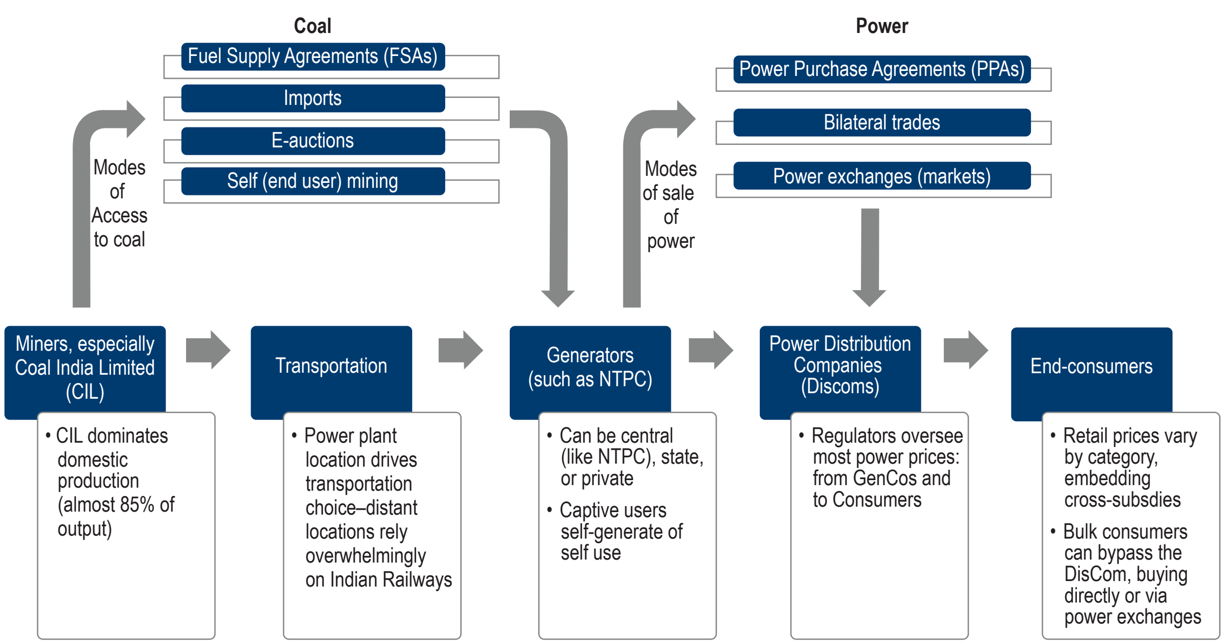
Figure 3: India's gross electricity generation by source



Thermal includes all fossil fuels, but is predominantly coal. Data exclude captive power. Terawatt-hours = billion kilowatt-hours (kWh) or Billion Units.

Source: CEA Monthly Reports Executive Summaries, 2012-18.[8]

Figure 4: Coal to Power Flows in India



The various choices for modes of access to coal and sale of power are shown in roughly decreasing share.

and non-payment). Figure 4 shows a typical value chain for coal to power. Prices can vary greatly among actors: For example, an independent power producer may not have a power purchase agreement, or a pithead power plant may save transportation costs by avoiding the railways.

DisComs purchase most power through power purchase agreements, which are mostly long-lived (frequently 25 years) with simple formula for generator cost recovery. PPAs for coal-fired power have separate fixed (capacity) and variable (fuel) charges. Fuel cost is a pass-through and tariffs generally allow a stipulated rate of return. PPAs do not distinguish between the firm, dispatchable power that coal-fired power plants generate and the intermittent supply that RE provides. In 2017-18, just over 90 percent of power was purchased through PPAs. Of the remaining 9.8 percent, a large fraction was transacted through bilateral trades; the day-ahead market only covered 3.5 percent of power. [9]

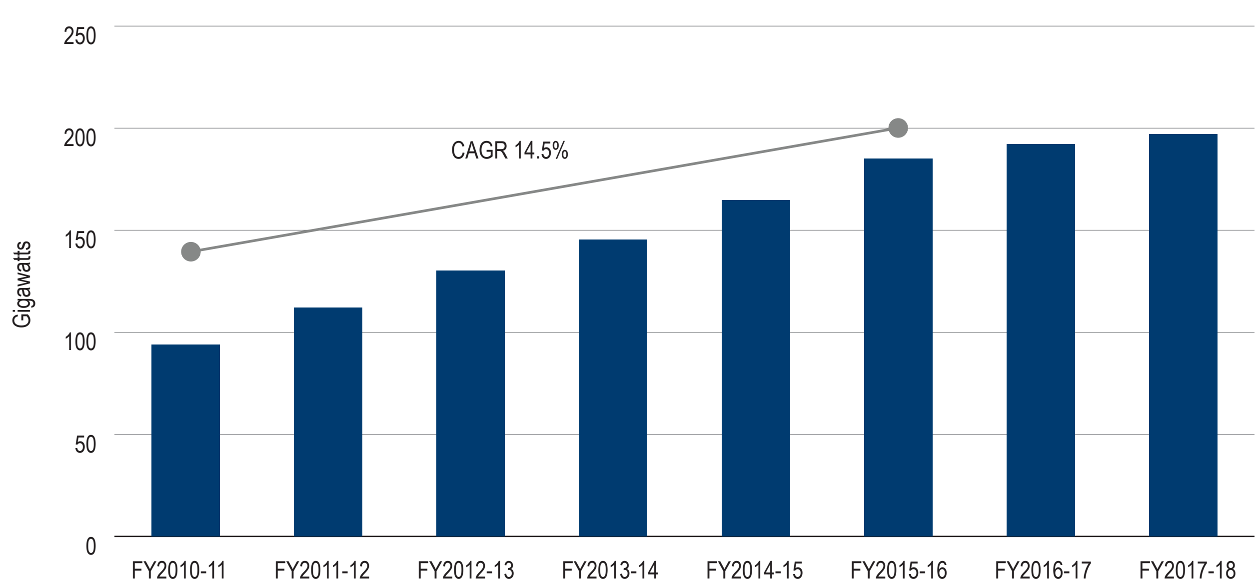
From scarcity to (near) sufficiency in power

Scarcity has been a major factor in India's electricity policy over the decades. Per capita consumption is very modest, less than 900 kilowatt-hours (kWh) annually, despite enormous capacity additions in the last decade. Electrification is an ongoing process. Every village in India was electrified by April 2018, meaning that at least 10 percent of homes in the village have electricity. Electrification is progressing rapidly, and as of January 2019, there are just 600,000 homes left to be electrified.[10]

Beyond connectivity, India's electricity sector was plagued with regular and extensive shortfalls, manifesting as brown-outs, euphemistically called "load-shedding." Over the last five years, these have steadily diminished because supply finally caught up with demand. Demand growth also slowed due to increasing energy efficiency and the dominance of services in gross domestic product (GDP), resulting in decreasing GDP elasticities.[11]

Coal-fired power made up most of the increase in generation capacity in recent years, with FY2010-11 to FY2015-16 annual capacity growth of 14.5 percent (Figure 5)[12] compared to overall electricity demand growth of 6.6 percent in the same period (Figure 3). The private sector built most of this new coal-fired capacity, but not all of these plants have a PPA.

Figure 5: Coal generation capacity in India



This excludes captive power.
Source: Indian Central Electricity Authority annual reports

As the new plants came online, not only had demand growth slowed, but the central government was also pushing for RE deployment. In 2014, the newly elected Narendra Modi government announced ambitious plans to quadruple RE to 175 gigawatts (GW) by 2022, an annual growth rate of 25 percent. Although generation from RE will be much lower than that from a coal plant of equal capacity, RE's aggressive growth is already displacing coal generation. RE's share of generation is only 7.8 percent today, but would reach about 19 percent by 2022 if RE targets are met.[13]

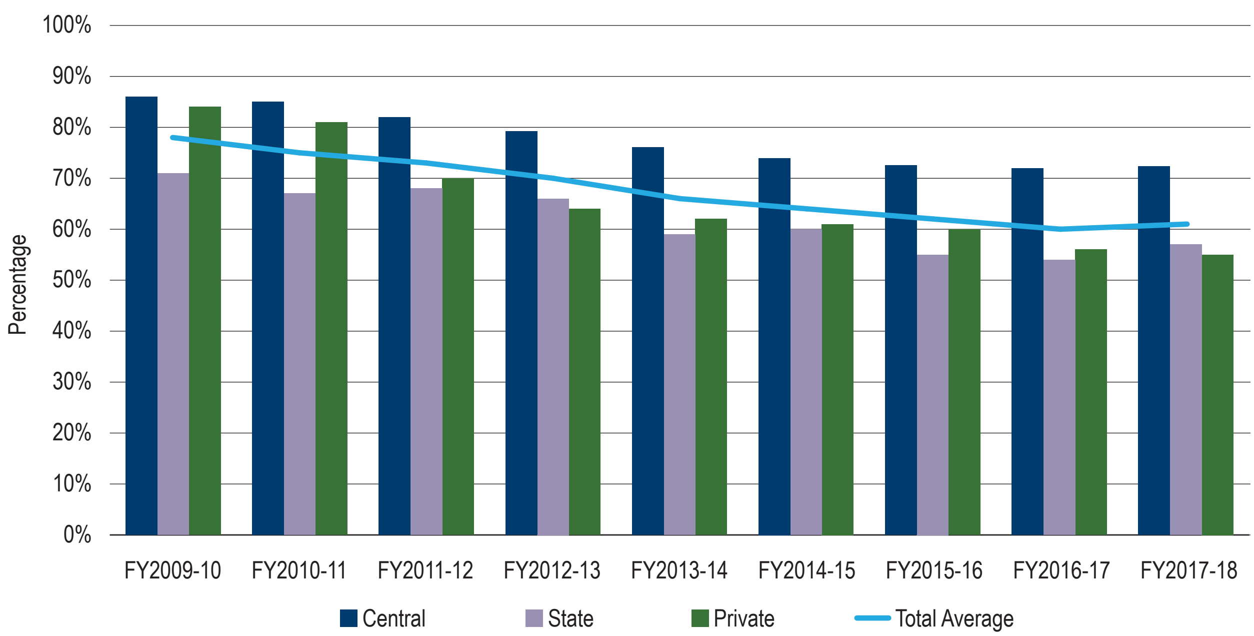
By many measures, India has surplus generation capacity—the installed gross capacity is approximately double the maximum load served. The dichotomy between apparent surplus and periodic load-shedding reflects some genuine shortages at specific locations or times of day. But it also reflects DisComs not buying power at times when it is available because they simply cannot afford it. Sometimes available power is more expensive than the DisComs' average cost, and the average costs are such that they lose money on every kilowatt-hour sold.

Thanks to the rise in generating capacity, plant load factors (PLFs) for coal plants have been falling over time (Figure 6), meaning that there is excess capacity from coal plants that could be dispatched. This problem is likely to worsen, since approximately 65 GW of power plants are under some stage of construction, with about 50 GW progressed beyond paper plans.[14] While all types of plants have seen a fall in output, privately owned plants have been hit the hardest, especially some newer and more expensive plants that lack a PPA. There is a strong split among central, state, and private power plants in terms of their utilization.

Coal India Limited: Structure and challenges

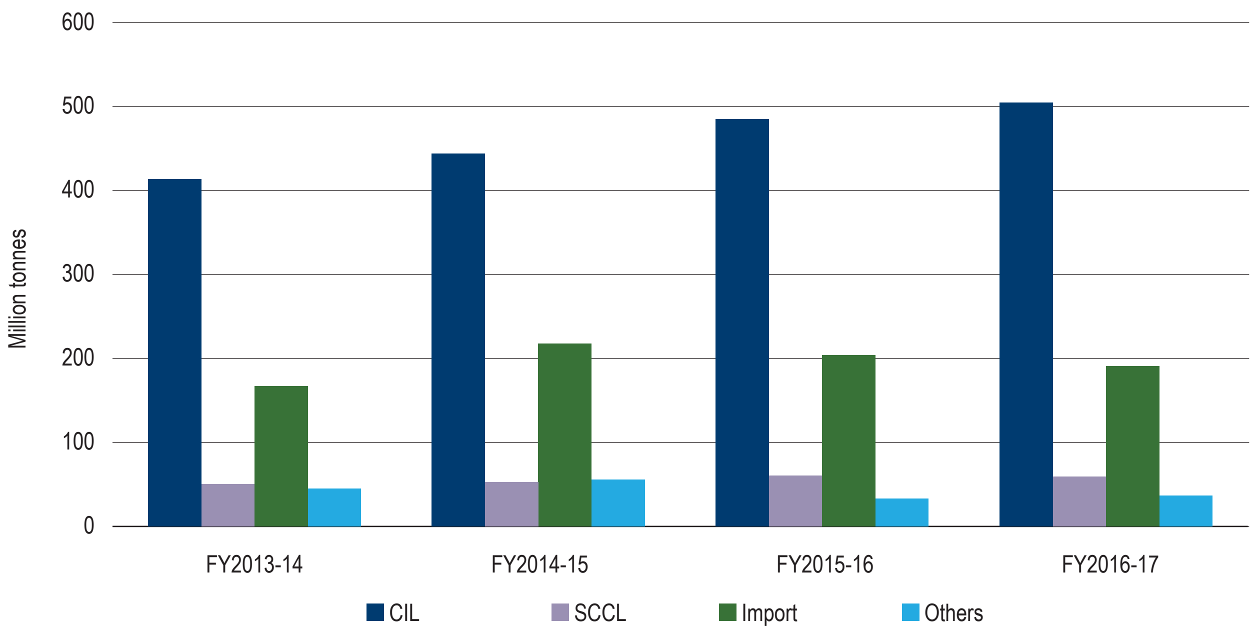
Access to coal has been a prized and valued asset since the time of the British. After independence, a handful of private operators dominated coal mining, but they were unable to meet rising needs, leading to the nationalization of India's coal industry in Financial Year (FY) 1971-72. These entities later amalgamated into Coal India Limited (CIL). CIL is a public-sector enterprise that today pro-

Figure 6: Generation plant load factor (PLF) over time



Source: https://powermin.nic.in/en/content/power-sector-glance-all-india. 2017-18 data are provisional.

Figure 7: Coal production by miner (excludes coking coal)



Note: SCCL is Singareni Collieries Company Limited, a south India-based public sector enterprise. Others are a range of domestic (primarily captive) miners.

Source: CIL, SCCL, and Indian Ministry of Coal annual reports

duces 84 percent of India's coal[15] and is the world's largest coal mining company (Figure 7). The government directly holds a 75-percent stake in CIL, providing significant revenue to the Exchequer through an annual dividend.

CIL has seven mining subsidiaries spread across different regions of India, each with their own cost structures and labor burdens. Some of the subsidiaries barely make money, while a few provide most of CIL's profits.[16] For many years after its creation, CIL relied on government largesse to meet payroll, a task made harder by a bloated workforce. CIL became more streamlined and professional when government support dried up after the 1991 economic reforms, and these advances in efficiency continued ahead of CIL's 2010 initial public offering, which created one of India's most valuable companies.

CIL production has fallen short of demand for much of its existence. Coordination and planning are the primary challenges, including obtaining approvals for opening new mines or expanding operations. Environmental clearances can take years and land acquisition is a perpetual challenge in a densely populated country. A 2011 policy to classify land where coal mining is allowed based on forest cover parameters made the problem worse by eliminating a number of already-allocated coal mining blocks. Railway linkages and chokepoints are also a concern.

In response to coal shortages, in the 2000s the government allowed end-users to produce their own coal. The central government initially allocated so-called "captive" mines, but a Supreme Court ruling found this to be a loss to the Exchequer. The allocations were cancelled abruptly and the mines were subsequently auctioned. The government has also proposed increasing the role of privately owned coal mines. However, neither of these actions addresses the underlying challenges of obtaining clearances and acquiring land. Additionally, it is unclear where and what quality mines the government might make available for captive or private mining.[17]

Pricing and the value chain

Domestic coal delivered to power plants has three significant cost components: the coal itself, government levies, and transportation. Transportation costs are substantial, depending on location, and the government charges a range of levies, split between the federal government and the state where the coal is mined. Levies and transportation costs are high and have been growing far faster than CIL's prices. Figure 8 shows trends in these costs over time, averaged across all coal end-users.

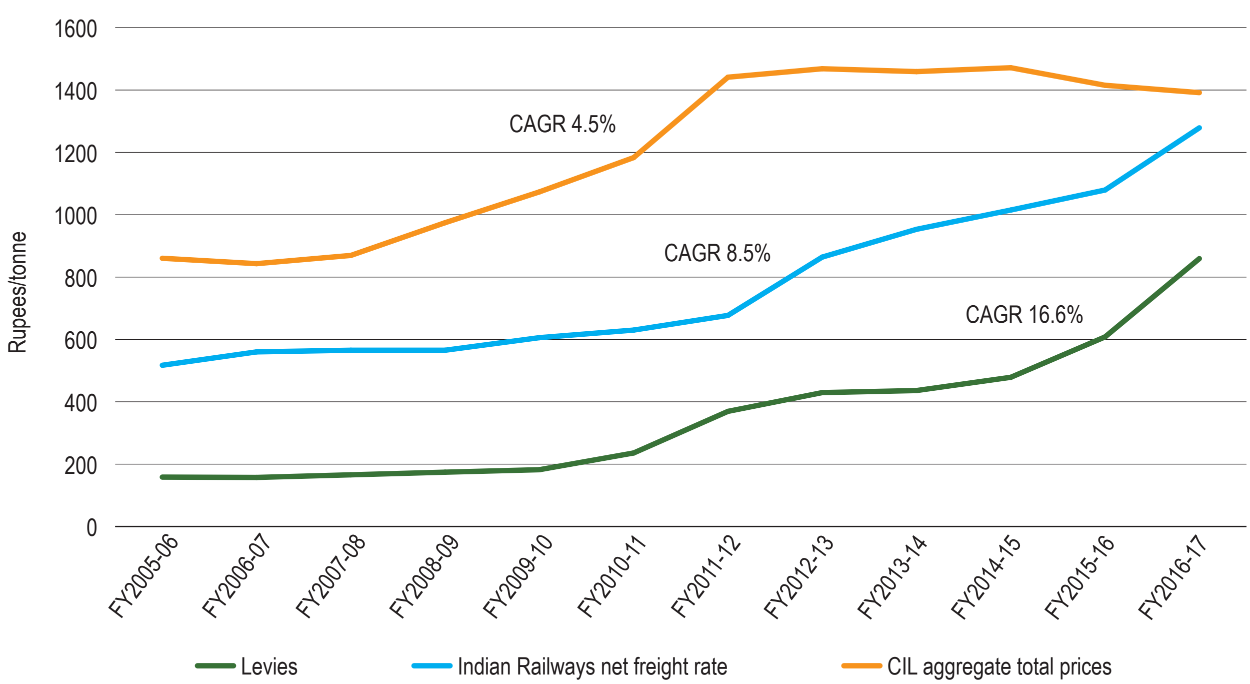
For comparison, coal costs for Indian power plants are about 50 percent higher than the United States on a per kilowatt-hour electricity basis.[18] Part of this gap is the higher energy content of U.S. coal, but levies and transport costs in the Indian coal supply chain are also an important component.

Coal fuel pricing

CIL sells its thermal coal at notified prices that vary by grade. A CIL committee sets these prices, working with the central government. The notified prices differentiate between coal destined for power plants (which is cheaper for most applicable grades) versus other uses, and apply only to coal sold via fuel supply agreements. Ten percent of CIL's output is allowed to be sold through an electronic auction that garners higher prices,[19] up to 60 percent higher when coal supplies are particularly scarce. Coal is prioritized for end-users that have fuel supply agreements and the higher auction prices reflect the scarcity of additional coal.

At the beginning of 2018, the CIL notified price for median grade coal to power plants was approximately 850 rupees/tonne. CIL can also apply other charges above the notified price, including local transportation and sizing charges, which can be 100 or more rupees per tonne. Some users buy additional coal at a higher price from auctions (for those without fuel supply agreements or those who need additional coal) or imports (used by many plants for blending with domestic coal to improve the energy content). Holders of fuel supply agreements

Figure 8: Historical trend of the primary components of delivered coal prices



CIL aggregate total prices are for all types of coal sold by CIL, for all user categories and all modes of sale (notified prices and auctions). Rail prices are for a notional 611 kilometers (km) of transportation, inclusive of loading/unloading fees and other surcharges.

Source: Underlying data from Indian Railways' freight circulars for respective years and CIL's Annual Statement of Sales and Levies, as calculated in Kamboj and Tongia (2018).[20]

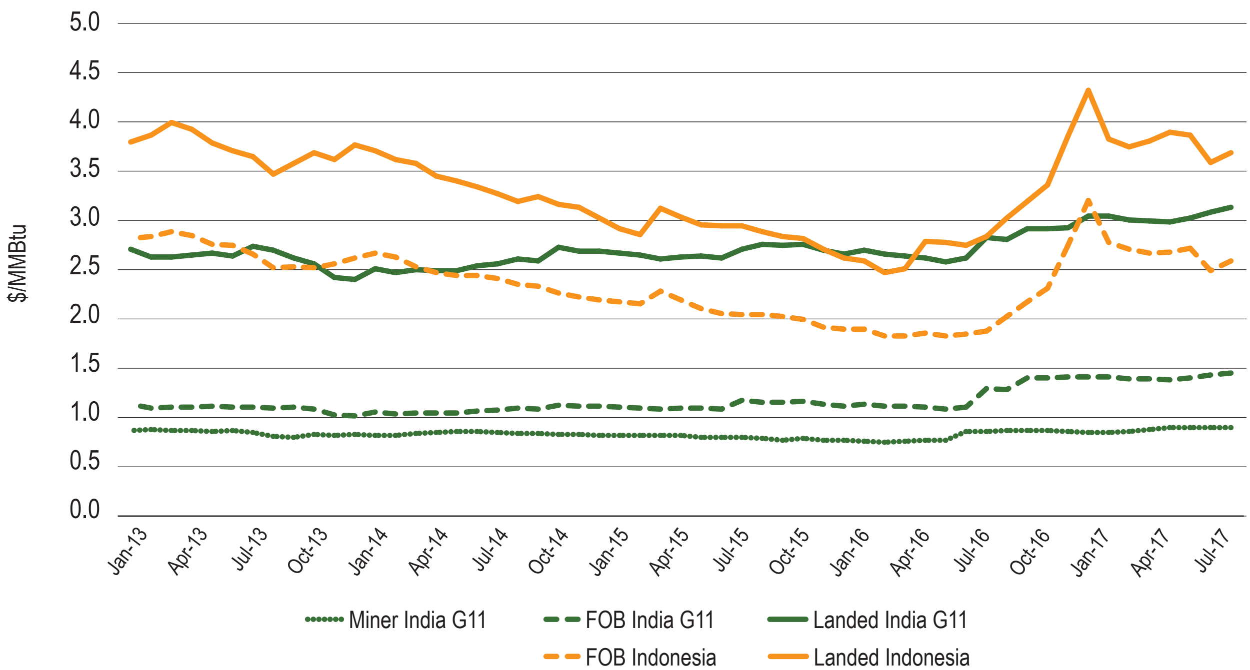
also pay bonuses to CIL when it delivers more coal than the base contracted amount.

Average coal consumption in Indian power plants is approximately 0.62 kg/kWh, leading to an average pithead fuel cost of a little under 1.4 rupees/kWh, including government levies. Newer, more efficient supercritical coal plants use at least 10 percent less coal than the average. Thus, 1.2 rupees/kWh is a useful reference point for fuel costs for future pithead power plants. Depending on the grade of coal, nearly half of this total is paid to the Exchequer in the form of levies and CIL's dividend payments.

To understand how Indian coal prices compare to other sources of coal, the low calorific value of Indian coal necessitates comparing prices on an energy basis. Imported coal can have energy content as much as 50 percent greater by weight than the median G11 coal delivered to the Indian power sector. High-grade Indonesian coal is comparable to Indian coal grade G4, which made up only 2.9 percent of coal production in FY2016-17, most of it going to non-power consumers. Some coastal power plants are designed to run on such high-grade coal, while others import lower-grade coal more similar to that produced by CIL.

Figure 9 shows how Indian and Indonesian coal compete in coastal power plants.[21] Although Indian G11 coal is cheaper than Indonesian coal on a free on board (FOB) basis, high transportation costs within India make up most of the difference for coastal power plants located far from Indian mines. On a landed basis, Indonesian coal is quite attractive most of the time.

Figure 9: Comparison of Indian and Indonesian coal costs



Prices in Indian rupees increased steadily over the time period, as the rupee depreciated by approximately one-third against the U.S. dollar. Prices are for Indian G11 coal and a similar grade of Indonesian coal. CIL miner prices exclude levies and are based on prevalent notified prices, plus mandatory charges such as sizing, crushing, and local transport. FOB prices include government levies, and landed prices are for a hypothetical coastal power plant 1,000 km from the mine. Landed costs for Indonesian coal include Indian government import costs (GST plus 400 rupees/tonne coal cess) and port handling charges estimated at 200 rupees/tonne.

Sources: Indonesia: HBA Prices, Ministry of Energy and Mineral Resources, Indonesia and Wood Mackenzie; India: calculated from CIL, Indian Ministry of Coal, and Ministry of Railways pricing notifications.

Coal levies

All domestic coal is subject to a number of levies, including 14.5 percent royalties, 5 percent taxes under the Goods and Services Tax (GST) regime, and mineral development fund charges. Some levies are per tonne, not per unit of energy, disproportionally increasing the costs of lower grade coals, such as those commonly used in Indian power plants.

Additionally, domestic and imported coal are subject to a coal cess that has risen from 50 to 400 rupees per tonne since its introduction in FY 2010-11. It began as a clean energy cess to support growing RE, and then became a clean environment cess to fund activities such as cleaning up the Ganges River. Since 2017, revenue from the cess has been used to compensate states for their losses under the new GST regime. The annual revenue is measured in billions of U.S. dollars, and today comes to 1.3 percent of the central government budget.[22] Total levies are about 859 rupees per tonne, a figure higher than the 2017 retail price of Western coal in the United States. In fact, even the miner prices for Indian G11 coal are higher than the FOB prices for U.S. Western coal.

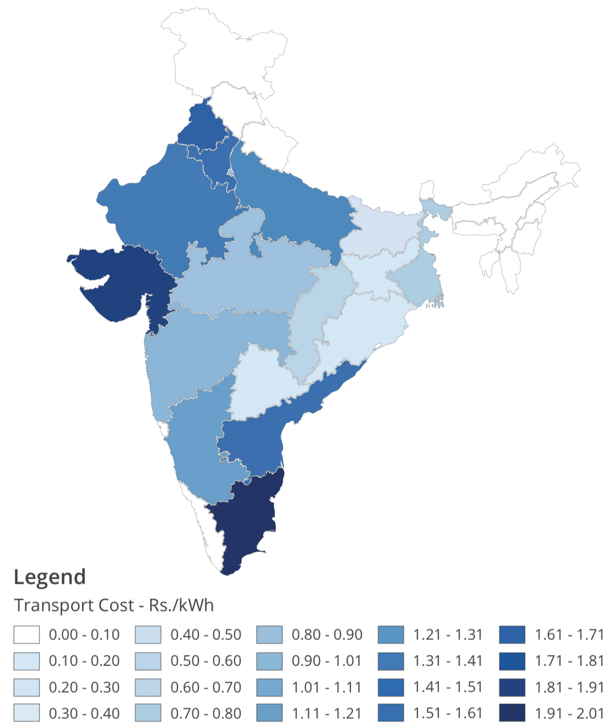
Coal transportation

Transportation is the key variable in the cost of coal delivered to power plants. Coal-fired power plants are located around the country, with an increasing number of pithead (or mine-mouth) power plants built more recently.

Power plants further than about 200 km from the mine generally use rail transportation. Pithead power plants often use dedicated infrastructure to move coal, such as conveyer belts or merry-go-rounds. Locations close to mines use trucks. Rail linkages also rely on trucks to connect mines to the railhead.

Railways account for roughly 87 percent of the cost of coal transportation.[23] The average transport distance by rail in 2017 was 496 km, a decrease of over 200 km in just five years thanks to changes in plant utilizations as well as a transportation rationalization exercise. States far away from mines transport coal as far as 2,000 km. For a state like Punjab, coal transport cost can be as much as 2 rupees/kWh (Figure 10), compared to about 0.10 rupees/kWh for local pithead plants using a conveyer belt.

Figure 10: Map of representative 2017 transportation costs across Indian coal power plants



Calculations assume national average specific coal consumption of 0.63 kg/kWh for all states. State values represent the highest transportation cost for a power plant in the state to show the greatest range. A value of zero means that either there is no coal transportation by railway or no coal-fired power plant in that state.

Source: Kamboj and Tongia (2018)[24]

The political economy of coal in India

The coal industry is knit into the fabric of the Indian economy. CIL provides significant revenue to the national treasury through dividend payments and is the largest employer in some regions of India. Levies on coal are an important source of revenue for the central government, and especially for coal-producing states, among the poorest in the nation. Coal levies make up as much as 7 percent of the budget for the Indian state of Jharkhand,[25] and several percent for a number of other states, even before we consider the employment and local economy effects of coal.

Indian Railways' freight charges for coal subsidize passenger transport. Passenger fares only cover 57 percent of the average cost of passenger transportation—this fact is printed on every passenger ticket. Freight is priced based on the type of commodity. Coal bears the largest burden because of its rate as well as high volume. Coal was the highest-volume commodity carried by Indian Railways in 2017, at 39.6 percent of freight volume and 44.1 percent of revenues.[26] Even using a lower-bound estimate of the subsidy, a coal-fired power plant in Punjab could be paying over 0.60 rupees per kWh of generation to subsidize rail passengers.

The market advantages of government-owned coal plants

Although the private sector led the expansion in coal-fired capacity from 45.5 GW in FY2013-14 to 75.6 GW in FY2017-18,[27] private-sector coal plants are now feeling the squeeze in a number of ways. Conversely, government-owned plants have many advantages, particularly those owned by the National Thermal Power Corporation (NTPC). NTPC is the coal generation behemoth, publicly listed but majority-owned by the central government.

For power plants, getting a fuel supply agreement to guarantee coal supply has always been challenging, both politically and commercially. Secure supplies of coal have always been a source of political and economic power, for specific plants as well as states. Coalition politics have increased the challenge and put pressure on fuel supply allocations.[28] The private sector also complains that public sector entities, especially NTPC, have better access to limited coal supplies.

Privately owned plants that lack a PPA are utilized less and struggle to pay their loans. As the Indian Parliament has acknowledged, lack of PPAs and low plant utilization have made the coal-fired power sector a significant contributor to Non-Performing Assets.[29]

Until requirements were changed in 2011, NTPC signed PPAs with DisComs without going through a bidding process, although bidding was mandated for private players to enable transparency and lower prices. In just three months before the January 2011 deadline to mandate bidding, NTPC signed over 40 GW of PPAs through memoranda of understanding, bypassing bidding.[30] This squeezed the private sector, which was efficient and price-competitive, but reliant on the monopsony buyers (the DisComs). NTPC also benefits from preferential access to scarce coal and plants located near coal supplies, resulting in lower generation costs and higher utilization rates.

Financing and other needs

Readily available funding for coal-fired power plants was an important contributor to India's current capacity overhang. The government dominated investment in electricity generation capacity after the 2008-09 financial crisis amid optimistic projections of both GDP growth and power demand. In an analysis of 125 coal projects over 1,000 megawatts in size, financed between 2005 and 2015, the Center for Financial Accountability found that 82 percent[31] of funding was from Indian government-controlled lenders. Three lenders dominated, two of which were controlled by the Ministry of Power. Given today's overcapacity of coal-fired power plants, public sector banks and lenders are facing the greatest stress. Bailouts are more politically-defensible and likely for public sector lenders.

International financing for coal projects has nearly dried up, with the exception of Asian sources. China has been particularly active in projects reliant on Chinese technology. However, coal isn't of interest to global pension or sovereign funds, sources that could provide cheap capital.

Competition among generation sources

Bidding for power plant development was meant to draw in competition, especially from the private sector. However, it is unclear if bidding for coal generation plants actually lowered power prices, unlike the aggressive bidding seen for solar and wind projects. Fewer players have the ability to compete in coal generation—coal projects require deep pockets and long time horizons, while RE projects can be much smaller and completed in one to two years. Additionally, the cost of power plants is not the only driver of electricity price. Delivered coal prices have been rising over time, but power plants with PPAs can pass this cost through to the DisCom, and on to the final consumers. This structure drastically reduces competition between coal plants with versus without PPAs.

The price of coal is an important factor in how power plants are dispatched, and thus their utilization rates. State load dispatchers ostensibly choose which plants run in a given power demand time block based on marginal costs, subject to technical constraints. Lower-priced coal plants win, and not having a PPA has been fatal to some plants. Plants attempting to sell non-PPA capacity on the power exchanges are especially beholden to fuel costs, which set a floor on bid prices, and rising surplus capacity means power exchange prices have fallen when viewed on a multi-year horizon.[32]

Distortions in the ecosystem and the need for competitive markets

India has a long way to go in creating truly competitive electricity markets, but they are essential to enable RE generation to grow alongside coal. Tweaking existing policies, especially those that continue downstream pricing distortions, will not be enough.

Structural reform of the power sector is needed, but the government has limited appetite for taking on this reform. Additionally, the central government can only do so much, as many problems are at the state level. The participants in the coal ecosystem—miners, railways, power plants, DisComs, and consumers—are in a delicate, but distorted equilibrium. Rationalizing these distortions requires finding a new equilibrium among the market players, a difficult political task.

Examples of market distortion abound:

- Some consumers specifically want green power, but a large portion of those installing rooftop solar do so because of enormous distortions in retail electricity prices. For example, commercial and industrial consumers overpay for electricity to subsidize agriculture and most households. If those distortions were removed, consumers focused on price might not be as motivated to turn to rooftop solar.

- Coal power plants that do not have PPAs would love to sell power directly to consumers. Although competition (known as open access) is allowed for large consumers, DisComs resist retail competition for fear of losing their best customers. They resist through overt means, like transmission and wheeling surcharges and cross-subsidy surcharges, and covert means, such as delays in permitting and other "technical difficulties."

- Procurement of power from generators makes up more than 75 percent of DisCom costs.[33] In the coal power value chain, CIL and generators with PPAs are virtually assured profitability, but the DisComs must sell power at regulated prices. These prices are intended to allow DisCom cost recovery, but are often set using assumptions that the DisComs cannot meet. This structure also removes incentives for generators to find cheaper fuel supplies. True competitive markets would require competitive pricing for both coal and power, a substantial market change.

- Many stakeholders agree that coal plants in India need to be cleaner and more flexible in their operations, to lessen environmental impacts and ease RE integration. How to operationalize these goals is the billion-dollar question. Some older and dirtier plants may need to shut down, but they currently provide the cheapest power for some states.

- Private-sector coal plants are generally newer, and thus cleaner and more flexible. However, fewer private-sector plants have the fuel supply agreements and PPAs needed to be competitive in India's market environment. A more flexible market structure would allow operators to monetize the benefits of these plants, rather than suffer the negative impacts that today's structure imposes.

The future of coal in India

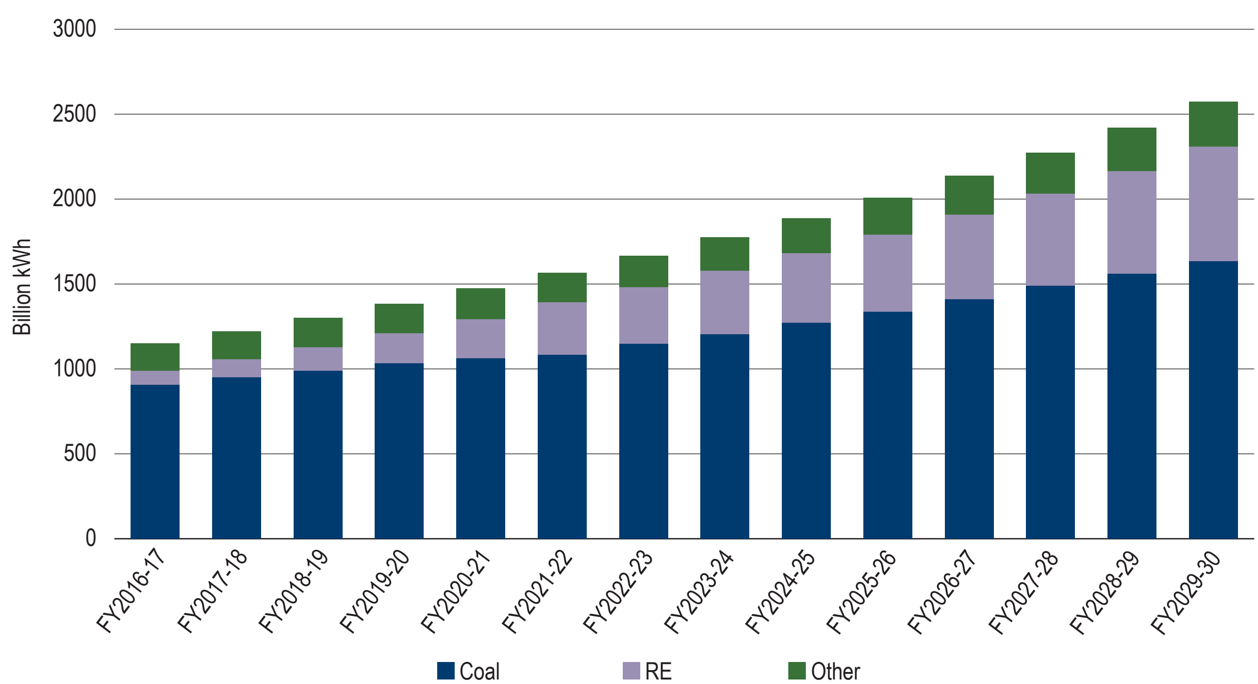
Coal is a low-cost fuel for power generation in India today. Rising RE capacity and broader changes in the power system mean that coal demand growth will slow, but we do not expect coal demand to peak before 2030 (Figure 10). Even if 350 GW of RE capacity is in place by 2030 (a more likely scenario than the announced ambitious goal of 175 GW by 2022),[34] coal-fired generation will still grow to meet anticipated electricity demand growth. Coal will remain the residual source of power given that hydropower faces socio-economic challenges to growth, India lacks cheap natural gas (which is prioritized as a feedstock), and nuclear power growth is likely to be limited.

Will there be enough RE to displace new coal? A simple calculation based on balancing units of energy shows that achieving the 2030 RE targets would not produce enough kWh to avoid growth in coal generation (Appendix 1). However, this does not necessarily mean that new coal *capacity* is required, as existing plants could generate more power (based on currently low PLFs). Additionally, around 50 GW of coal capacity is already under construction.

Growing coal generation is not the only possible outcome. Coal use in the power sector could plateau, but a number of conditions would need to be met: higher RE growth, high load factors for RE, modest power demand, greater coal conversion efficiency, and growing hydro and nuclear generation. However, modeling such an outcome would require a much more sophisticated analysis, with consideration of time of day, location, transmission, ramping requirements, minimum generation from a plant, and so on.

As a base case (Figure 11), we project around 4.6 percent annual growth of coal-fired power generation through 2030. However, the growth in coal demand will be somewhat lower (about 3.6 to 3.8 percent annually), as the growing share of supercritical coal power plants will raise the average fleet efficiency, and we also anticipate efficiency gains in industrial use.

Figure 11: Projected end-use electricity generation in India, by technology



Details of assumptions for the 2030 projection are given in the appendix. The calculation of aggregate electricity demand in 2030 comes from a study by Sahli Ali[35] at Brookings India.

Which coal power plants will be competitive?

As we consider coal's future, not all coal-fired plants will be equally competitive. Environmental, operational, or other policies that affect coal will have a wide range of cost implications based on the plants' vintage, technology, duty cycle, and location. Not all plants are capable of responding to grid conditions and policy mandates.

The Central Electricity Regulatory Commission mandated in 2015 that coal plants be able to reduce output to 55 percent of capacity in response to grid conditions, particularly at times of high RE availability. All power plants built this decade are already required to have such capability, but for older plants, compliance may require extensive upgrades, raising the cost of power from such plants and making them less competitive with other power sources.

India has been behind the curve in deploying new technologies for coal-fired power generation. India only began deploying efficient supercritical power plants in the last few years and does not yet have ultra-supercritical plants. Few plants have installed sulfur dioxide removal technologies like flue gas desulfurization, owing to India's relatively low sulfur coal. However, in 2015, the Ministry of Environment, Forests, and Climate Change established rules that require such equipment, not just for new plants, but also as a retrofit for most existing plants. When implemented, these will bring India in line with the most stringent norms in the world.

Older plants have a limited remaining lifespan and lower expected PLFs, making it more difficult for them to recoup the cost of environmental upgrades. Stakeholders asked for more time to comply with the new environmental rules, and the deadline has been extended to 2022. Although air pollution is a hot-button topic, especially in Delhi, most studies indicate that coal power plants are not the primary source of urban air pollution, because most plants are built far from cities.[36]

The relationship between coal and RE

RE is the elephant in the room when considering the future of coal. RE should be dispatched before coal since it has no operating cost, and therefore power demand net of RE generation is the important figure for coal. We estimate 6.4 percent annual growth in overall power demand through 2030, but only 4.6 percent growth in coal power demand.

Newspaper headlines routinely proclaim that RE is cheaper than coal, with bid prices of 2.44 rupees/kWh for solar compared to new coal pricing of that is closer to 4 rupees/kWh. However, this is not an apples-to-apples comparison. RE costs are the levelized cost of energy only, and do not include system-level and hidden costs. More importantly, these costs do not reflect the time of day when power is available. India's peak demand is usually in the evening, which clearly does not match solar output and does not always match wind's peak generation. Nonetheless, the overwhelming majority of power today is purchased through PPAs that treat all power the same, regardless of when it is available.

All coal users pay into society through levies, railway subsidies, and earnings from CIL. In contrast, RE enjoys substantial support. Until recently, there were explicit RE subsidies. RE also receives benefits such as free transmission and wheeling, avoidance of cross-subsidy charges, and discounted or aggregated land at solar parks. Additionally, RE raises costs on the rest of grid through reduced output, increased ramping requirements, and reduced efficiency of fossil-fuel plants operating at partial capacity. The Central Electricity Authority (CEA) estimates these costs today as 1.5 rupees/kWh, excluding land support.[37] Over time, we anticipate that hidden costs will fall as RE prices fall and the grid strengthens, but the implications will not be equal across India.

Development time is an underappreciated difference between coal and RE. Coal power plants, coal mines and rail tracks take years to develop, and, once built, developers expect such infrastructure to run for decades. In contrast, RE technology (especially solar) can be built much more quickly. This raises the risks of stranded coal assets, with costs that are almost inevitably socialized.

Today's surplus of coal-fired power capacity puts pressure on RE in terms of dispatch. PPAs for coal plants have separate capacity charges (fixed costs) and variable fuel costs, while RE PPAs have only a single charge visible to the load dispatcher. This asymmetry means the marginal *contractual* cost of calling an additional unit of thermal power can be lower than for an additional unit of RE, an anomaly. To correct this problem, central government rules mandate that RE is a "must-run" source of power when it is available. However, DisComs often resist if calling on RE raises their costs, sometimes under the guise of "grid security."

The fuel cost of coal is often lower than even the most optimistic average RE cost projections for the coming years, especially for pithead power plants. Power demand growth combined with retirement of some older or dirtier power coal power plants will eliminate the current surplus in coal generation capacity over time, but RE will not be able to meet all future energy requirements. Instead of a clear cost point at which RE becomes cheaper than coal, the reality is likely to involve steps of competitiveness, depending on location, whether storage is required, and whether one compares total or variable costs.[38] RE with storage has a long way to go to compete with the variable cost of existing coal plants, especially ones at the coal pithead.

Slowing investments in coal-fired power

The enormous rise in coal-fired generation capacity in the 2010s was a response to shortfalls years ago. Now the pendulum has swung in the other direction and no one is building new coal plants beyond the estimated 50 GW of capacity already under construction.

A number of challenges are discouraging new capital investments in coal-fired generation. Existing surplus capacity and the resulting low PLFs, combined with growing RE capacity, raise the question of how much new coal-fired generation is needed. Additionally, the DisComs' financial challenges lead them to reduce their offtake and at times delay payments. Coal power plants are one of the largest categories of stressed assets in India. International capital for the coal sector is also limited, especially in mining, with the exception of Asian financing for power plants built using their technology.

The lack of enthusiasm for coal investments is also based on a belief that renewables will be more cost-effective, even without a price on carbon. Although many decisionmakers understand the difference between baseload and intermittent power, they often believe that storage technologies will soon eliminate the need for new coal-fired power. Natural gas-fired generation also offers a lower-carbon pathway that is more complementary to RE. India has limited natural gas production, but it has ambitions to increase supply via imports and new exploration. However, liquified natural gas (LNG) prices make this expensive for baseload power, and the government prioritizes gas supply for transportation, cooking, and feedstock.

India does not currently need new investment in coal-fired power plants, but enormous investments will be required in pollution control technologies at existing plants. Although these will be expensive, they will offer positive benefits in terms of mortality and morbidity, with many estimates suggesting a highly positive societal payback.[39] As coal generation costs rise—due to emissions control equipment, as well as investments and operational changes to allow more flexible operations in response to rising RE—coal plants may become less competitive from a local dispatch perspective.

India's coal production: Improved regulation and policies needed

The flip side of peak demand is peak supply—can India produce the coal that it needs? A simple calculation shows that India has more than 300 years of coal reserves at the current production rate, including proven and likely reserves.[40] Domestic coal will still dominate in the future and is a priority for the government.

On average, lack of coal is unlikely to be a bottleneck for meeting demand, given the combination of modest output increases from CIL, rising private-sector or end-user production, and imports. Issues of cyclic production, bottlenecks, and seasonal variation can lead to short-term shortages best dealt with through better coordination and oversight, such as the mandate for a minimum stockpile at power plants.

The question is how India's coal mining industry will be structured. Captive mining has not led to significant increases in production. Coal customers also have limited appetite and ability to operate the mines, except through private mining operations companies.[41] The central government has drafted a policy to enable private commercial mining, allowing open sales to any consumer. However, the underlying objective is unclear. The expectation is that global players can bring greater efficiency, but private mining will not solve the fundamental challenges of increasing India's coal production—coordination and planning, land acquisition, and obtaining necessary approvals.

CIL will remain the mainstay for India's coal supply—any new entrant will take years to develop a mine. Even if one assumes that CIL is bloated (efficiency varies greatly by subsidiary and even mine), bringing in the world's best, state-of-the-art mining practices and technologies is unlikely to significantly decrease costs. CIL production is reasonably cheap and most end-user costs are not a function of mining costs.

The cost of coal mining depends far more on the quality of the mine than on optimal management. If the coal is deep underground, then the mine will cost more to operate. CIL's prices are averaged over the range of mine quality. CIL's most profitable subsidiaries are those with the best quality mines, meaning that they require the least amount of overburden removal. CIL is afloat primarily because about half of its output comes from two low-cost subsidiaries. Low costs at these mines subsidize higher costs at others, and coal is sold at a blended notified price per grade (except for a single subsidiary with higher notified prices).

So how would private competition help? If private miners are more efficient than CIL, they would offer a backstop against rising prices. Private-sector competition would bring differentiated pricing based on costs, instead of today's cross-subsidy model across CIL subsidiaries. Private players would be free to set prices and CIL would have to respond, lest they lose their most profitable customers.

Private players could also help increase domestic output, if they could navigate the challenging stakeholders and bureaucracy. But private mining companies would be interested only in large mines with an estimated output of 30 to 50 million tonnes per year. The government would also want more than one private miner, for transparency and competition. More than one additional large miner would produce enough to affect demand for CIL's coal. Thus, it is no surprise that CIL labor unions have stalled current plans for private commercial mining, at least until after the 2019 elections.

The National Institution for Transforming India (NITI Ayog), the government's planning arm, suggested breaking up CIL in its 2017 draft National Energy Policy. A breakup would end cross-subsidization among the parts of CIL that have different cost structures due to mine quality. Customers across India could then face very different coal prices. However, the parts of a broken-up CIL would be unlikely to compete for customers, since mine location is so crucial for the cost of coal delivered to power plants.

Regulatory focus on CIL operations is less important than other potential changes in the coal ecosystem, including rail freight rates, power plant locations, and taxes and levies. Moving from public to private coal production would only modestly lower costs. Beyond costs, increased competition might help coal quality and consistency, something end-users would welcome.[42] This is a major reason to encourage competition, even if the share of private miners remains modest.

Conclusions

India wants RE for many reasons, but it also needs coal. Coal will be essential to meet ever-growing power demand resulting from greater affluence, especially from air conditioning, which is projected to be the largest source of demand growth in the coming years. Coal is also central to India's political economy, as an essential revenue source for the central and state governments and for Indian Railways, the nation's largest civilian employer.

Coal and RE are both needed to meet India's energy needs

India announced its ambitious RE targets before the Paris Agreement in 2015. The RE targets are only a subset of India's Nationally Determined Contribution to the Paris Agreement, and they reflect a desire not only to reduce carbon emissions, but also to add new power capacity with new sources of capital. Even with tempered but growing coal consumption, India is on track to meeting its Paris commitments.

India needs far more power—its per capita consumption of electricity is only one-third of the world average. RE and other clean energy sources are not ready to entirely displace coal, but the recent fall in RE costs increasingly makes it a "no regrets" option, up to a limit based on the rest of the grid. Although removing coal from power generation is a popular goal, few countries have actually done so beyond what market forces would have done on their own. For example, the rise of shale gas in the United States reduced coal's share of power production, not RE.

India faces a balancing act between controlling carbon emissions and developing at the lowest cost. India is still a mid-to-lower-level developing country, especially when viewed from a human development perspective. India's recent Chief Economic Advisor, Arvind Subramanian, has observed that India must be cautious of hype and not suffer from "carbon imperialism." India is unlikely to lead in deep decarbonization, but India's contribution to global emissions is modest today, especially when normalized on a per capita basis.

Policies that consider coal and RE together as part of a broader supply portfolio, rather than engaged in a zero-sum-game, will make integrating RE into the Indian power grid easier. The current overhang of coal-fired generating capacity makes RE economics more difficult than they would be if India were in deficit. Rigid PPAs that treat all power the same make RE integration more challenging, since they provide no incentive for development of flexible power resources to complement RE. Storage technologies will be needed to deploy more RE than can be absorbed by opportunistically displacing fossil generation at the margin. Up to this level, RE looks cheap and easy; the limit is linked to the capacity factor of the RE generation.[43] For example, if we install 200 GW of solar, and the noon demand averages 200 GW, then any higher solar capacity requires storage or risks curtailment. At such a capacity, assuming a flat load, solar would only provide about 20 percent of the energy requirement, based on its bell-curve shaped output curve.

India is likely to face more challenges at lower levels of RE penetration than other countries due to its weaker grid with limited fast-ramping capacity and its evening demand peak. The DisComs are watching the growth of RE with both hope and fear: hope that RE prices and storage prices continue to fall, but fear that they may soon have surplus energy on average, with periodic deficits at particular times of day.

Rather than a singular focus on RE, demand-side options are also important to enable low-carbon development. India, like many countries, under-invests in energy efficiency. Efficiency is diffuse and more difficult to implement, and also can result in a lower return on investment because it is largely an operating expense rather than a capital expense. Efficiency investments also frequently encounter the agency or split incentive problem. Most Indian construction is done by builders who have no incentive to consider the life cycle cost of the building. A systems approach and holistic view of energy, environment, and development is needed.

India still has low-hanging fruit on the road toward deep decarbonization. There is room for expansion in mid-day RE, followed by some storage for RE generation located far from coal mines. Only then, some years from now, will India face the challenge of displacing the least expensive existing pithead coal plants.

The mid 2020s will be an interesting time for India's power system. The coal capacity overhang is likely to go away. By that time, either storage technologies will have matured, or India will need some other source of generation, especially in the evening. In the absence of time-of-day pricing that could incentivize peaking power plants, demand response, and storage, India may need additional coal power plants. But these plants take years to plan and build. Increasing RE generation will have already stretched India's grid and made the economics of traditional coal more challenging, owing to falling PLFs. Something will have to change.

Coal's role in the economy makes transition more challenging

Coal supports society through levies, CIL profits, and by subsidizing railway passengers. This societal support makes up one-third or more of the total delivered price of coal to power plants.[44] Coal is also a significant employer in some of India's poorest regions. As coal begins its transition from pure dominance to gradual decline, the government will have to manage the fiscal and political expectations of these stakeholders.

Indian Railways will particularly suffer as the Indian coal market changes. Older coal-fired power plants are disproportionately state-owned, and thus spread out across the country. Pithead plants are more attractive for new development due to their vastly lower coal transportation costs. The value proposition for pithead plants is increasing further as the national power grid strengthens and high voltage DC transmission enables shipping power over thousands of kilometers. Additionally, RE potential is disproportionately higher in southern and western India, far from the coal mines. Coastal India also has the option of using imported coal at prices that are competitive after factoring in high domestic transportation costs. All of these trends result in less coal transport by rail, posing an existential challenge to the railways' revenue model, which explicitly overcharges coal to subsidize passengers.

Some coal stakeholders are hedging their bets. NTPC, the largest coal power producer in India, produces about one-quarter of India's power. It aims to leverage its leadership and balance sheet to become a serious player in the RE space, with a 32 GW RE target by 2032. However, it is not clear how much NTPC's investment will increase RE penetration, rather than displacing other players from a relatively finite market.

One way to avoid the political challenges of coal's eventual decline may be making Indian coal cleaner instead of wishing it away. More efficient coal-fired plants reduce carbon and other emissions, but are more capital intensive. A vibrant, competitive landscape of technology providers, perhaps with global support, could enhance reduction in emissions. Although the world has ignored coal in India in recent years, it would do well to engage to help spur a transition to cleaner energy that includes coal. Improving efficiency and reducing emissions are not just a large market opportunity, but also an enormous social imperative for India. If one makes inexpensive capital available for RE investments, the same capital might result in greater carbon reductions by making India's coal sector cleaner or increasing end-use energy efficiency.

Removing distortions in how generation is dispatched would reduce emissions from today's coal fleet. Very efficient plants without PPAs frequently lose in today's system. Additionally, state DisComs may dispatch state-owned power plants more frequently, driven by the luxury of delaying payments to state assets. These outcomes result in greater emissions than would result from efficient dispatch. Coal transport costs also impede dispatch based on efficiency, because the high cost of transportation makes less efficient plants closer to a coal mine appear cheaper than more efficient plants located further from the mine.

India has not shown the will to achieve deep, structural improvements in the coal sector and the power sector, and their inter-relationship makes incremental change that much harder. The government has not cleaned up power plant emissions, despite numerous studies showing that the costs of cleaning up, while large, are lower than the human health and life benefits.[45] Funding the capital investment of tens of billions of dollars over just a few years is challenging, even though the amortized cost is low, estimated at a few tenths of a rupee per kWh (or around 0.5 U.S. cents) on average. The coal cess would have been an ideal tool to pay for this, but its revenue is now used to pay off GST differentials to states.

Coal will remain the residual fuel for electricity in the coming years. RE isn't ready to entirely displace coal, especially without viable storage. Domestic coal production capacity could be sufficient—better management of statutory approvals and land acquisition are more important than capital investment for increasing production. Domestic shortfalls can always be covered by imports, even if this is an expensive option with more market risk. CIL's future and regulation are important issues, but the ultimate existential questions are in the power sector. Distribution is the weakest link in the chain and has received far less investment than generation. Although the central government has periodically bailed out the DisComs and there is a current re-financing scheme, more radical action may ultimately be required, such as the unbundling between wires and retail under proposed Amendments to the 2003 Electricity Act.

India's energy transition will not be a simple binary change from coal to RE with a magic price point at which the switch occurs, but a location-specific and phased transition. Failure to recognize this could create a number of risks, ranging from failing to meet RE targets to meeting them but at higher than necessary costs, or with higher emissions than otherwise.

APPENDIX: Projections for renewable energy growth and share relative to targets[46]

	Type	Formula/notes		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
A	Input to the model	*Progressive growth through the periods*	RE capacity [GW]	*54.0*	68.3	86.4	109.3	138.3	*175.0*	190.8	208.1	226.9	247.5	269.9	294.3	321.0	*350.0*
B	*Assumed except 2017*	*Progressive improvement to match assumptions in red*	RE plant load factor (PLF)	*17.3%*	17.5%	18.0%	18.5%	19.0%	*20.0%*	20.0%	20.5%	20.5%	21.0%	21.0%	21.0%	21.5%	*22.0%*
C	*Modeled as per compound annual growth rates (CAGR)*	Demand CAGR assumed as 6.4% annually	Total utility generation [BU]	1149.0	1222.5	1300.8	1384.0	1472.6	1566.9	1667.1	1773.8	1887.4	2008.1	2136.7	2273.4	2418.9	2573.7
D	Calculated	A X 8760 X B	RE generation [BU]	81.8	104.7	136.3	177.2	230.2	306.6	334.3	373.7	407.6	455.3	496.5	541.4	604.5	674.5
E	Calculated	D - C	Other (non-RE) generation [BU]	1067.2	1117.8	1164.5	1206.8	1242.4	1260.3	1332.8	1400.1	1479.8	1552.9	1640.2	1732.0	1814.4	1899.2
F	*Assumed*	*Declining hydro share*	Share non-coal, non-RE	15%	15%	15%	14.50%	14.50%	14%	14%	14%	14%	14%	14%	14%	14%	14%
G	Residual	E - F	Coal generation [BU]	907.1	950.1	989.8	1031.8	1062.2	1083.8	1146.2	1204.1	1272.6	1335.5	1410.6	1489.5	1560.4	1633.3
H*	Calculated	D / C	Share RE	7.1%	8.6%	10.5%	12.8%	15.6%	19.6%	20.1%	21.1%	21.6%	22.7%	23.2%	23.8%	25.0%	26.2%
I	*Calculated*	*Annual difference*	RE growth [BU]	N/A	22.9	31.6	40.9	53.0	76.4	27.7	39.4	33.8	47.7	41.2	44.9	63.1	70.0
J	Calculated	*Annual difference*	Non-RE growth [BU]	N/A	50.6	46.7	42.3	35.5	17.9	72.5	67.3	79.7	73.1	87.3	91.8	82.4	84.8
K	*Calculated*	*Annual difference*	Coal growth [BU]	N/A	43.0	39.7	42.0	30.4	21.6	62.4	57.9	68.5	62.8	75.1	79.0	70.9	72.9
L	*Calculated*	*Annual difference*	Total growth [BU]	N/A	73.5	78.2	83.2	88.6	94.2	100.3	106.7	113.5	120.8	128.5	136.7	145.5	154.8
M	*Calculated*	*Annual difference*	RE growth year over year (y/y)	N/A	28.0%	30.1%	30.0%	29.9%	33.2%	9.1%	11.8%	9.1%	11.7%	9.1%	9.1%	11.6%	11.6%
N	*Calculated*	*Annual growth rate*	Other growth y/y	N/A	4.7%	4.2%	3.6%	2.9%	1.4%	5.8%	5.1%	5.7%	4.9%	5.6%	5.6%	4.8%	4.7%
O	*Calculated*	*Annual growth rate*	Coal growth y/y	N/A	4.75%	4.18%	4.24%	2.95%	2.03%	5.76%	5.05%	5.69%	4.94%	5.62%	5.60%	4.76%	4.67%
P	Assumed	*Linear growth to reach assume terminal value*	Coal capacity [GW]	185.0	189.2	193.5	197.7	201.9	206.2	210.4	214.6	218.8	223.1	227.3	231.5	235.8	*240.0*
Q	*Calculated*	*1000 * Coal Generation [BU] / (Coal capacity [GW] * 8760)*	Corresponding coal PLF	56.0%	57.3%	58.4%	59.6%	60.1%	60.0%	62.2%	64.0%	66.4%	68.3%	70.8%	73.4%	75.6%	77.7%
			Energy [BU] CAGR (until 2030)		6.40%		1st period RE capacity CAGR (until 2022)		26.51%					2nd period RE capacity CAGR (2022-2030)			9.05%

Note: This assumes targets are met for FY 2021-22 and FY 2029-30 as 175 GW RE and 350 GW RE, respectively, and overall demand grows at 6.4 percent in billion units [BU, or billion kWh], and calculation assumptions or starting points are shown in red italics. Coal capacity is not a bottleneck as generation is the residual calculation for coal (Row G). 240 GW matches one estimate of coal capacity in 2030 based on existing capacity, capacity already under construction, and modest retirement of older plants. We note there are some discontinuities in growth rates, which are an artifact of the 2022 aggressive timeline for RE. Green text indicates the share of RE over time.

* The generation share for RE (Row H) is higher than actual for 2017 as much of the capacity comes online towards the end of the year, and so doesn't contribute generation commensurate to the nameplate capacity throughout the year.

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