The Boston Consulting Group

Confederation of Indian Industry

Future of Coal-Based Power Generation in India

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FUTURE OF COAL-BASED POWER GENERATION IN INDIA

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EXECUTIVE SUMMARY

IN THE CURRENT IMPETUS on Renewable Energy by the Indian Govt., coal continues to remain the backbone of the power sector and the economy in general, primarily due to its contribution to total power generation and the multiplier effect it has on the economy.

Both renewable and conventional sources of fuel have a role to play in sustaining India's growth story. However, in the short term the two sources come in direct contest over the same resource pool: Investor funds, constrained procurer demand and government policy attention.

A number of challenges faced by coal-based plants have however increasingly put them at risk of being stranded.

Poor financial health of DISCOMs and debt overhang have created a situation of artificial demand scarcity: a significant number of houses remain to be connected to the grid or have 24 hour access, while DISCOMs continue to remain reluctant to sign new long term PPAs with GenCos. With PPAs often being a precursor to the allocation of FSAs, plants without PPAs are exposed to coal supply uncertainty. Fuel prices have also been on the rise over the past 6 years: a period in which imported coal prices have been falling year-on-year. A large number of projects have run into execution challenges leading to time delays and cost overruns.

50 GW of the total installed power capacity of India is stranded. Capital infusion and operational improvement have limited potential to turn these plants around. Performance remains strongly linked to government policy and strong policy intervention is required to shore up the stressed assets.

The long term outlook for coal is also far from heartening. Govt. policy directly and indirectly supports renewable capacity addition. With renewables achieving grid parity, there has been a reversal in the merit order of DISCOM. In addition, plants dependent on imported coal are also at a significant price risk (owing to the volatility of the index), as seen in the case of coal imports from Indonesia. This is in contrast to domestic coal where prices are fixed in the medium term period. There also remains very limited scope for new investment in this sector given the capacity addition planned over the next 5 years.

Going ahead, both renewable & coal-based plants have specific functions to play in the energy sector. Even in economies with higher dependence on Renewables, conventional plants continue to play a critical function as “Topping” plants. This is an outcome of intra-day fluctuations in demand and solar load and as such can only be partly mitigated through off-peak pricing. However, a major change is needed in the operations and management of conventional power plants to effect this shift from “Base load” to “Topping cycle”.

Incentives across the value chain need to be aligned with the objective of inculcating flexibility in operations. This also mandates the necessary technological changes to enable plants to run at lower minimum loads.

In order to balance the interests of coal-based thermal plants against the imperative to increase renewable capacity, key policy interventions are required. In addition, changes at coal suppliers and GenCos are needed to ensure that coal-based generation remains competitive.

In conclusion, while the recent growth of the power sector is a positive sign, the various stakeholders have to now re-evaluate the role of coal-based generation going ahead and accordingly adapt policy and operations to stay competitive in the new business paradigm.

INTRODUCTION

COAL FIRED GENERATION IS an integral part of the power sector as it serves as a base load as well as enables economy through job creation.

Coal As Base Load for Generation

For a growing economy like India, uninterrupted electricity generation and availability are key to stable economic growth.

India's electricity generation has grown steadily in the past, reaching about 1,228 BUs[1] from an installed capacity of around 330 GW. This period has been a phase of exponential growth for the energy sector with rapid capacity addition across the board over the last 2 years. With India's aspiration to continue to grow at a stable 7 percent p.a. as it has done in the past, reliable electricity supply for civil society & businesses is essential.

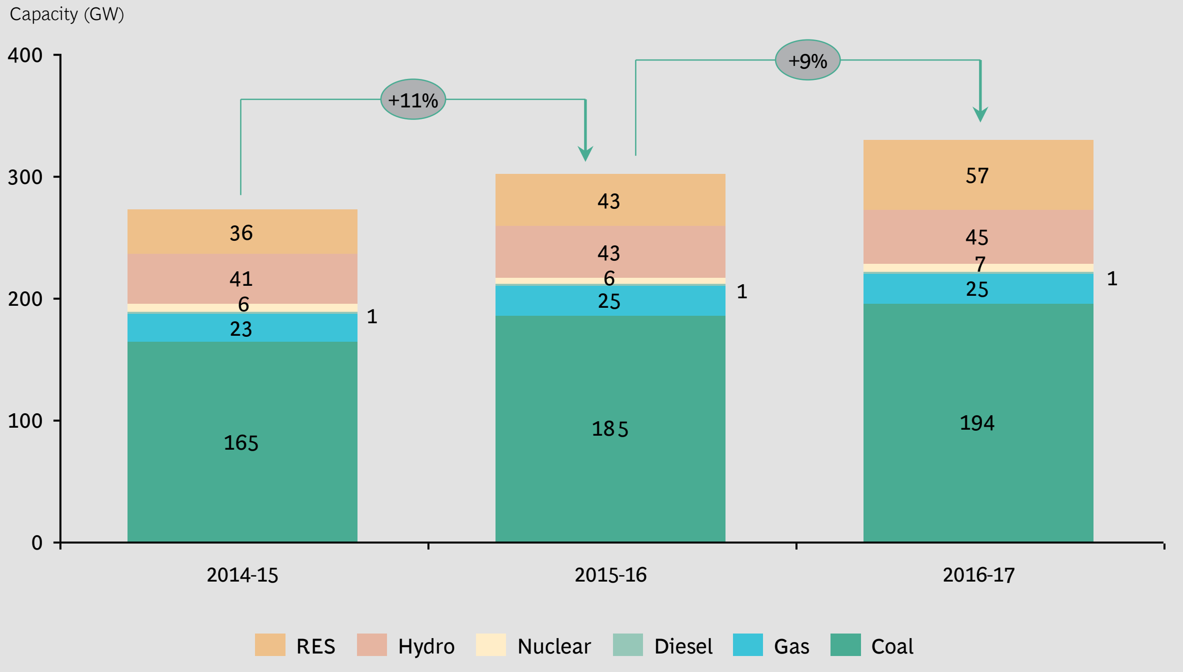
For more than a century however, the backbone of the power sector in India has been the thermal generation plants (coal-fired thermal plants, in particular). Of the installed base of 330 GW in 2017, coal-based power plants contribute almost 60 percent (~194 GW). Power generation from renewable sources has grown rapidly over the last 2 years replacing hydro electricity as the second highest installed base for electricity generation. Thermal Power has always historically accounted for more than 60 percent of the total generation capacity in the country.

Furthermore, over the last 2 years alone, the coal-based power generation capacity in the country has grown by nearly 29 GW, the most by any fuel type in the country (as shown in Exhibit 1.1). The 188 coal-based plants in the country account for greater than 70 percent of the total electricity generated (as shown in Exhibit 1.2). The conventional sources of power thus serve as the base load for the electricity demand across the country.

Conventional Generation As An Enabler of Economy

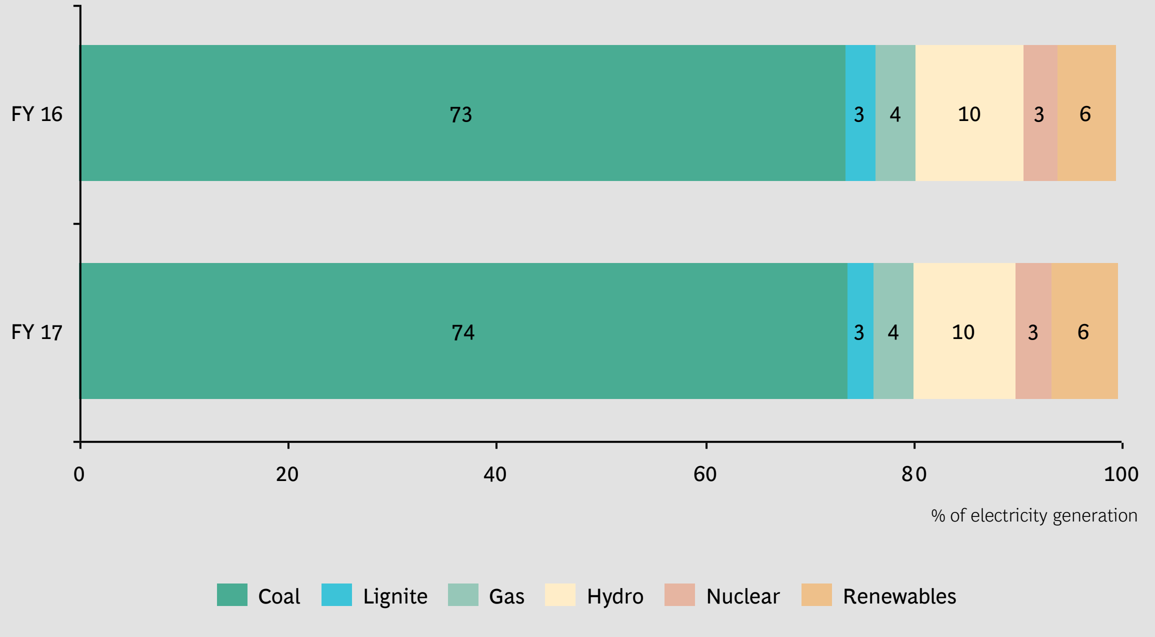
As a sector, the impact of coal-based power generation on the economy is far from insignificant. To fully assess the impact the sector has on the economy one must evaluate not just the direct impact that reliable electricity generation has on the economy (through job creation at the plants themselves), but also the indirect means by which the sector enables communities by creating jobs and opportunities in ancillary industries. Exhibit 1.3 shows how coal-based generating plants act as growth drivers for a vast number of industries—logistics, fuel, OEMs, EPC, Balance of Plant (BOP) and electrical equipments. The total impact of this sector on the national GDP & employment can be categorized along 4 key dimensions[2]:

Exhibit 1.1 | Historical Installed Generation Capacity by Type of Fuel



Source: CEA.

Exhibit 1.2 | Share of Electricity Generation by Type of Fuel



Source: ThomsonONE.

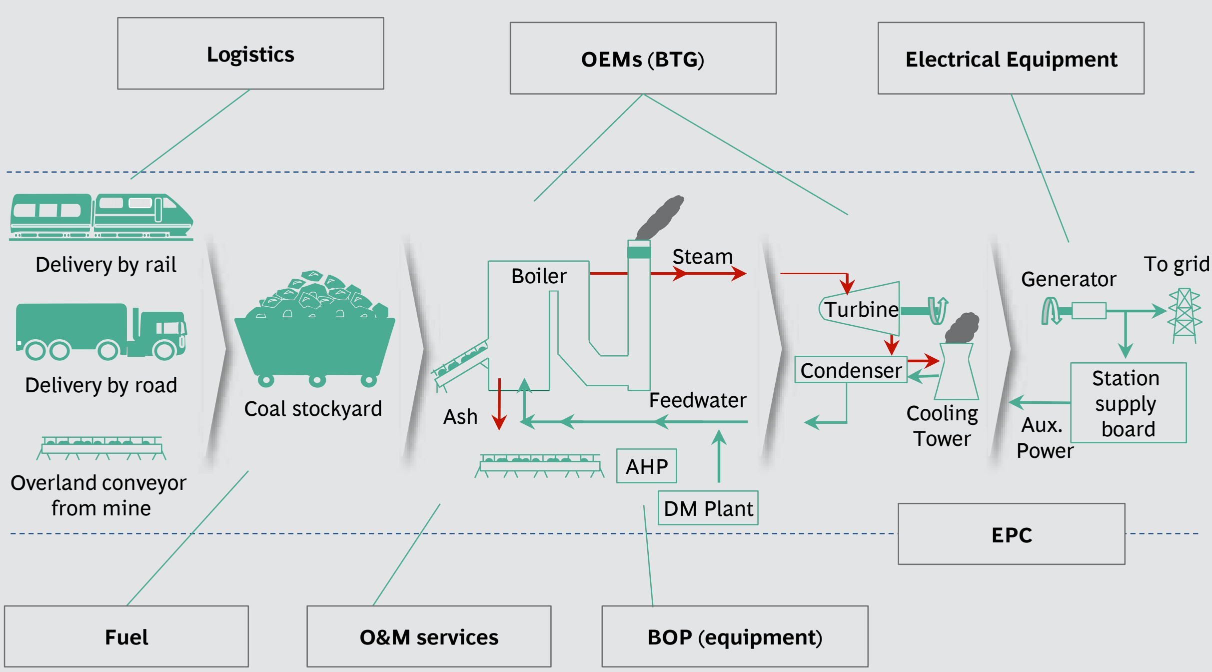
- **Direct effects**: Which relate to the direct employment (at the plant) and direct output (electricity) generated by the sector over its lifetime
- **Indirect effects:** Which relate to the incremental impact that the coal-based generation sector has on ancillary industries, including input industries, EPC services, O&M services, steel, cable and cement industries, instrumentation etc.
- **Induced effects:** Which relate to the spend and employment created by the expansion of power and allied sectors which in turn increase the overall spend in the economy through increasing the total demand
- **Second-order growth effects:** Which relate to the multiplier impact more economical / reliable electricity supply would have on downstream industries, boosting the total industrial output

Furthermore, this impact on the economy is created throughout the life cycle of a project: from the construction phase through the operational phase of the project. The construction phase of a conventional project has an economic multiplier of 1.48x (i.e., $1.48 of economic benefit for every $1 of investment in the project phase), while the operations phase of the plant has an employment multiplier of 2.8x (i.e., 2.8 jobs created for every job in the sector) (as shown in Exhibit 1.4)[3].

This is in contrast to renewable-based projects, where the bulk of the economic impact is created in the construction phase (Economic multiplier of 2.32). Furthermore, a significant fraction of the construction phase impact for solar projects is created in China (which has emerged as a manufacturing hub). The India share of value addition in the solar value chain is typically under 15 percent of the total investment[4], thereby weaning off the benefits accrued to India.

Thus, it is clear that both renewables and conventional coal-based plants have a role to play in sustaining India's stable economic growth both in terms of contribution to electricity generation and economy enablement.

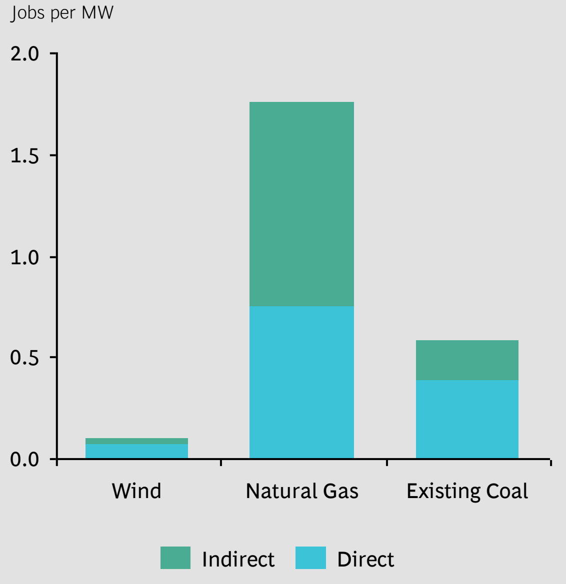
Exhibit 1.3 | Industries Dependent on Conventional Generation



Source: BCG analysis.

EXHIBIT 1.4 | Ongoing Employment in the Operations Phase of Electricity Generation in the US

EMPLOYMENT PER MW BY TYPE OF FUEL



ECONOMIC INDICATORS FOR OPERATING PHASE OF US POWER GENERATION FACILITIES

	Employment multiplier	Value added per direct worker
Solar PV	N/A	N/A
Wind	2	US$ 244,000
NGCC	1.5	US$ 130,000
Coal	2.8	US$ 152,000

Source: IHS CERA.
Notes: Solar PV not included in the graph because ongoing employment in the operation and maintenance per installed MW is negligible; Operations and maintenance spending is very small for solar PV and it is included in this analysis.

NOTES:
1. Load Generation Balance Report 2016-17. CEA.
2. Power Sector Economic Multiplier Tool, IFC.
3. Renewable Economies and State Economies, CSG.
4. BCG analysis.

CURRENT CHALLENGES IN CONVENTIONAL GENERATION

Given the criticality of coal-based power plants both to the power sector and more generally to the economy as a whole, it is extremely important that the sector remains competitive with active participation from government, public & private players.

However the sector as a whole is not without its share of problems, with adverse trends in demand, supply and efficiency combined with weak policy support for conventional generation heralding difficult times in the coming years.

A number of these challenges are structural in nature, contributing to the present woes of coal-based generating stations. These challenges can be categorized along 3 key dimensions—***procurer demand constraints, fuel supply risk*** and ***execution delays***.

Procurer Demand Constraints

Growth in energy demand has not kept pace with the rise in supply.

Poor financial health of DISCOMs has been a major bottleneck to increase in demand for electricity. With pending liabilities, DISCOMs have refrained from committing to long term PPAs. Most DISCOMs are burdened by debt overhangs which have only been growing since 2011.

DISCOM debt has grown at an alarming CAGR of 18 percent, to reach a total of INR 430 thousand crores (as shown in Exhibit 2.1). 85 percent of DISCOMs have a credit rating of B+ or less[1], impacting their cost of borrowing. Issues of high AT&C losses, insufficient tariff hikes and low subsidy collections from government continue to be rampant, ruining profitability.

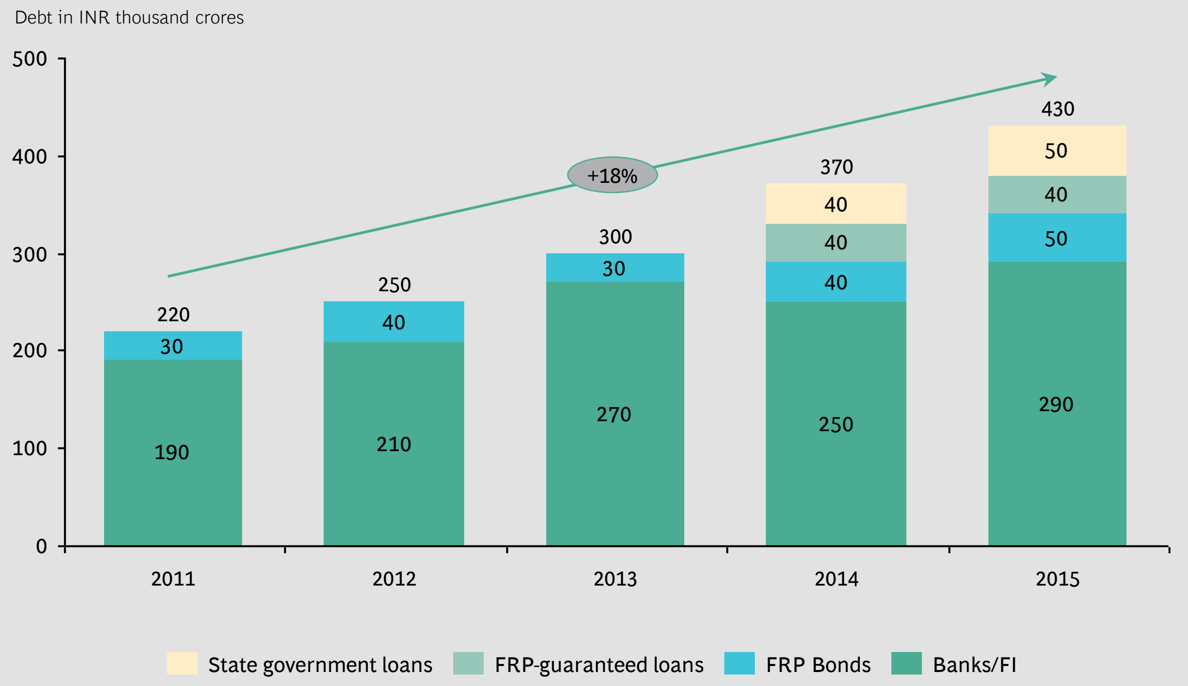
As a result only 14 GW of PPAs were announced in the period between 2012 to 2016[2].

This disproportionate capacity addition in the sector has created a situation of artificial demand scarcity. Out of 66 privately commissioned plants in 2016, 15 percent did not have any PPAs (as shown in Exhibit 2.2).

A number of power generation companies without capacity locked in PPAs have been exposed to the volatile prices of the short term market. This has been accompanied by a decline in the utilization of the coal fired power plants across the board. Exhibit 2.3 shows how the average Plant Load Factor has dropped significantly, from 75 percent in 2010-11 to 60 percent in 2016-17.

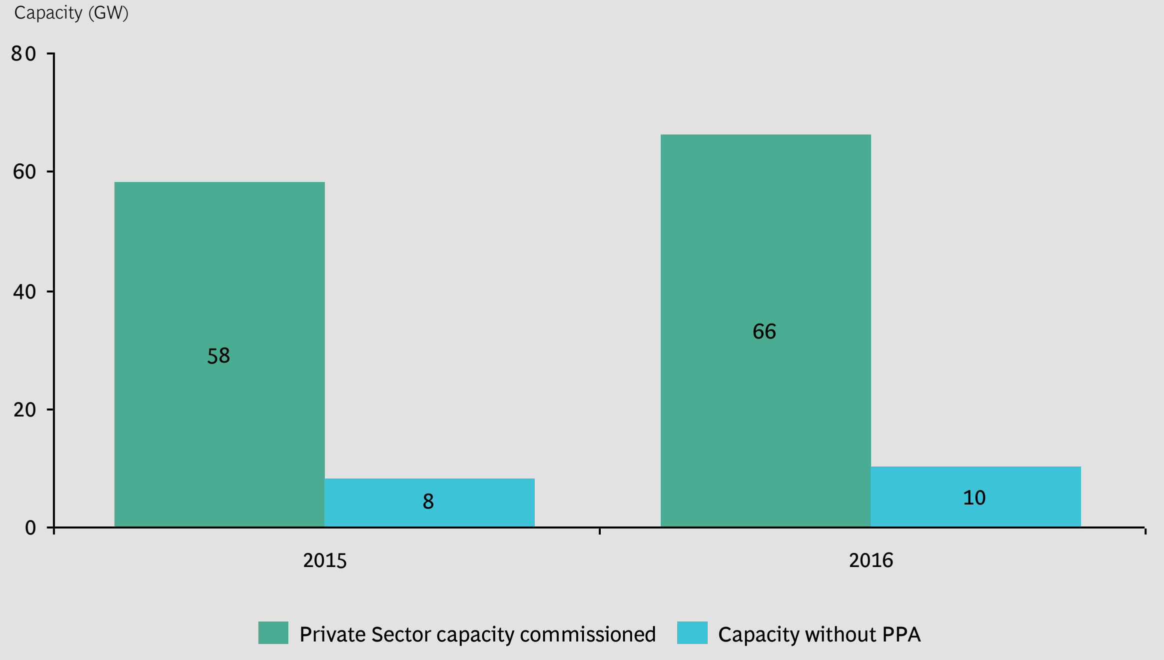
Although UDAY (Ujwal DISCOM Assurance Yojana) has improved the financial situation for DISCOMs by reducing their interest cost burden and AT&C losses, it is yet to drive confidence to invest in PPAs. With limited PPAs, prospects of future investment in the

EXHIBIT 2.1 | DISCOM Debt Split



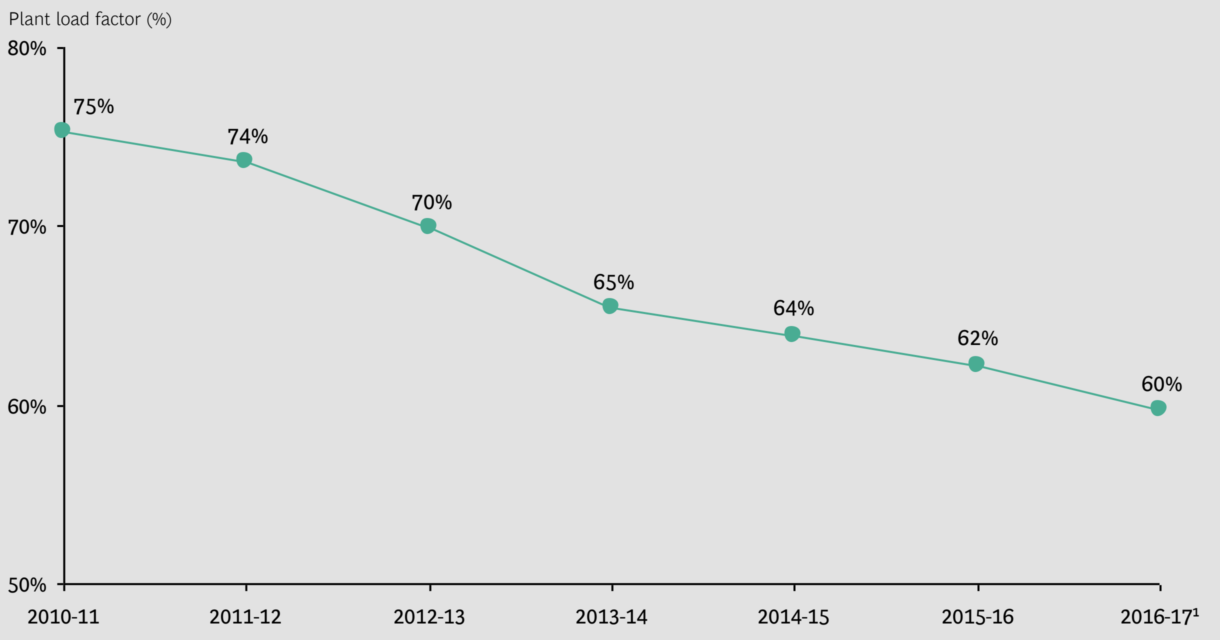
Source: CRISIL report.

EXHIBIT 2.2 | Private Sector Commissioning and PPA Availability



Source: CRISIL.

Exhibit 2.3 | PLF of Coal-Based Power Plants



Source: CEA.
[1]Provisional based on actual-cum-assessment.

sector seem bleak with many of the existing power plants without PPAs now becoming stranded assets.

There however is no shortage of demand for power. A bottom-up, back-of-the-envelope analysis reveals the existence of significant **latent demand**.

We are yet to achieve our goal of 100 percent electrification. Nearly 6 crore rural households and many urban households are still not connected to the grid and power supply in several parts of the country is limited to only a few hours a day.

Accounting for the potential of increased per capita consumption in rural households with improved access to electricity and the consumption of subsidized consumers like farmers who are not connected to the grid, there is an estimated latent demand for ~90 BU (as shown in Exhibit 2.4). After considering T&D losses and average specific generation (GWh / GW), the total latent demand is almost 29 GW[3]—~9 percent of the installed base of the country.

A clear business case exists for latent demand not converted into PPAs due to the weak financials of DISCOMs.

To further add to the woes of coal-based generation, increasingly stringent RPO / RGO obligations imposed by the Govt. have brought the sector in direct competition with renewable generation.

Not only do these RPO obligations impose an additional financial burden on DISCOMs, they also further dis-incentivize investment in conventional generation.

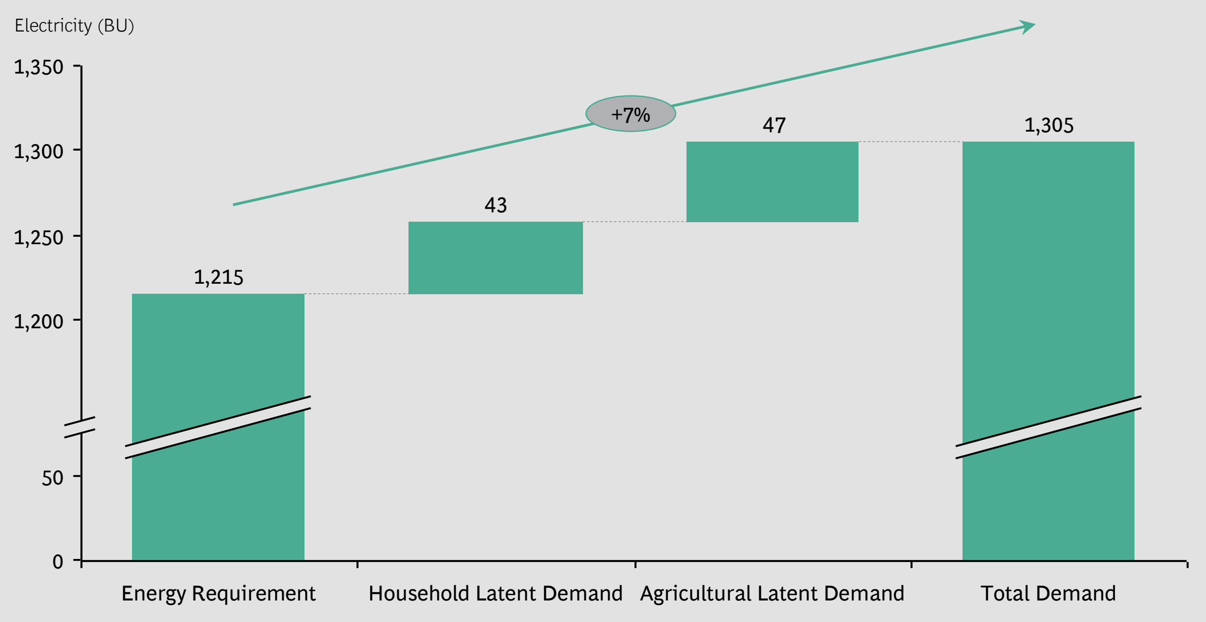
Fuel Supply Risk

Private players face 2 major sources of Supply risk:

- Availability of coal
- Landed cost of coal to generating stations

Private players struggle to source fuel for their plants given the government monopoly on coal supply. No new LOAs (Letter of Assurance)

EXHIBIT 2.4 | Total Energy Demand in India in FY 17, Including Latent Demand



Sources: Load Generation Balance Report 2016-17, BCG analysis.

have been given to IPPs over the last few years. Existing LOAs are also converted to FSAs only if the IPP has a long term PPA in place. Given the current demand situation with DISCOMs, this creates a vicious cycle. This also inevitably creates generation capacity which does not have a stable source of domestic fuel (owing to the uncertainty associated with coal auctions) and often with no or limited access to imported coal markets (due to the location of the plant making imported coal unviable).

While pithead prices for domestic coal are below those for imported coal prices on an absolute basis, an interesting trend is observed when current prices are indexed to their 2011 levels. Exhibit 2.5 illustrates that while domestic coal prices have been gradually increasing year-on-year over the past 6 years, with little or no correlation to global coal markets, imported coal prices have fallen over the same period.

With a bulk of the plants in the country operating on a "Cost-plus" model and primarily firing domestic coal for generation, this increase in prices has inevitably been passed on the end customer.

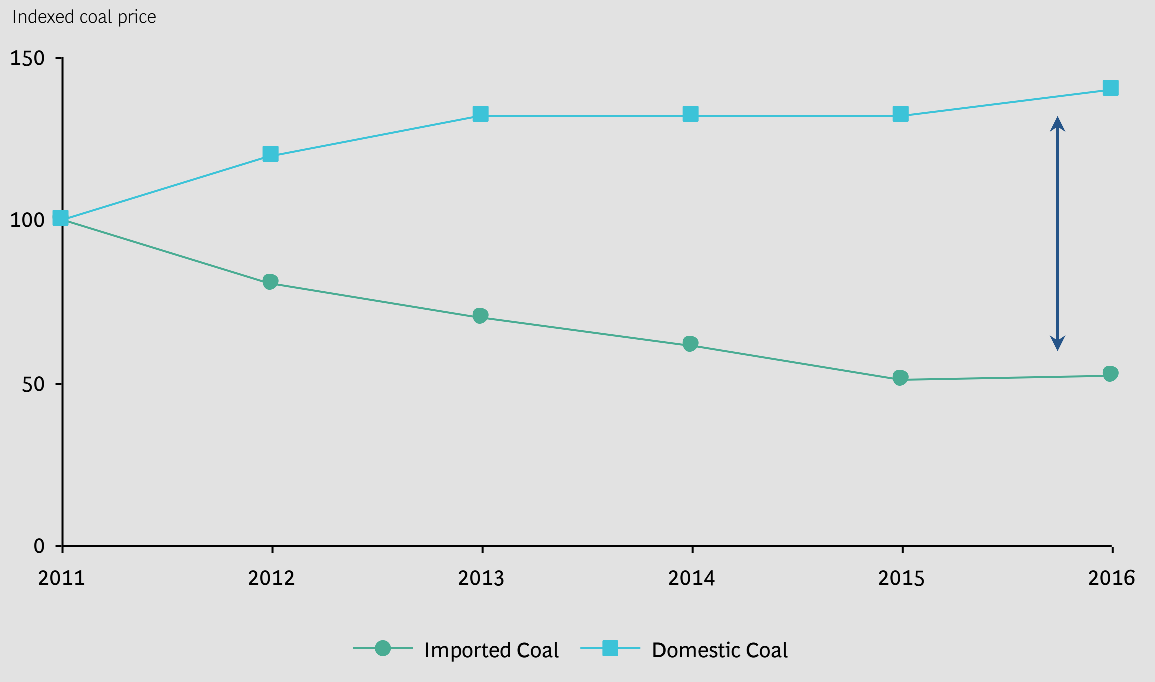
However, an analysis of fuel costs suggests significant potential to bring down the costs to the end customer through improvements to coal mining efficiency and government policy interventions.

MINE LABOUR PRODUCTIVITY

Although globally Coal India is among the lowest cost producers of coal in the world (driven by low strip ratios[4]), processing costs & labour productivity present significant potential for cost reduction, while maintaining CIL's margins.

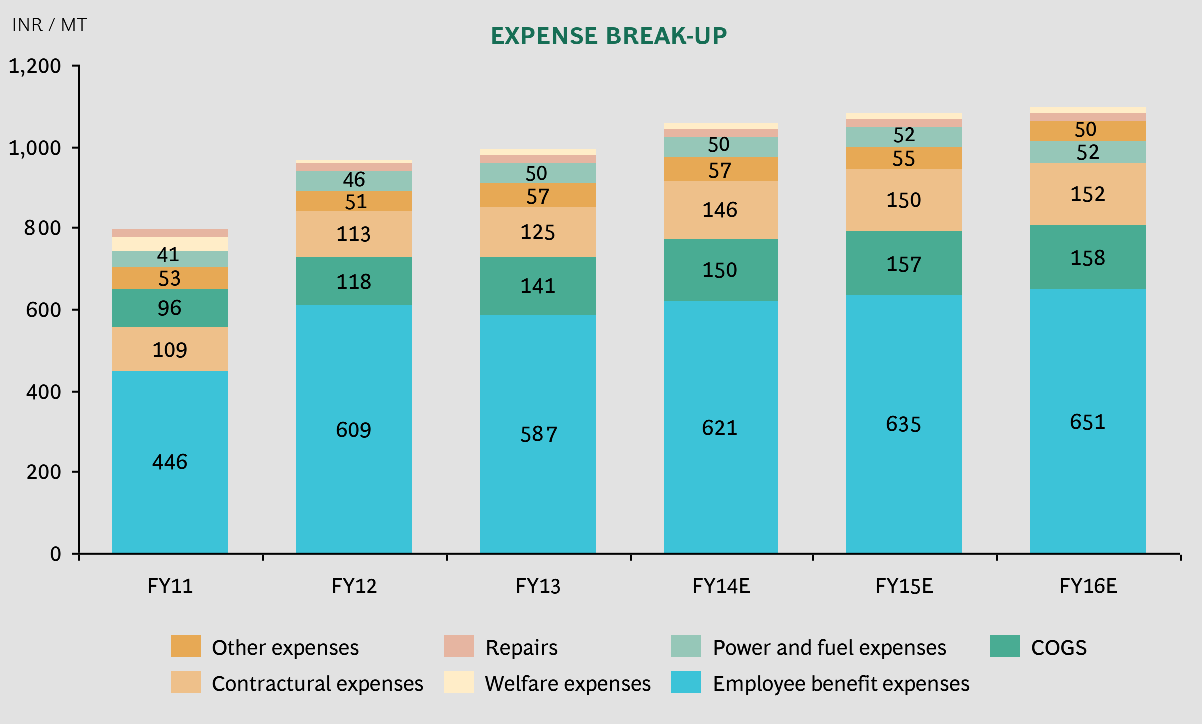
Processing costs in Coal India are of the order of ~$16 / MT while best-in-class mines with similar strip ratios (especially in the US) incur processing costs of the order of ~$10 / MT or INR 650 / MT(as shown in Exhibit 2.6). Nearly 50 percent of these processing costs for Coal India are Employee costs. Benchmarking the productivity of labour, Coal India's average output per man shift (a measure of productivity) was 6.2 tonnes for FY15 vs. the global average of more than 15 tonnes / man shift basis data from the World Coal Association. Thus, notwithstanding the lower cost of

EXHIBIT 2.5 | Historical Trend of Indexed Domestic and Imported Coal Prices



Sources: Coal India, World Bank, FOIS, Baltic Index.

EXHIBIT 2.6 | Expense Break-up of Coal India Limited



Sources: Company, ICICIdirect.com research.

labour in the country, there is significant potential to improve productivity through investments in capital equipment.

In addition, given that the strip ratio of Indian mines are projected to increase over the next few years (as shown in Exhibit 2.7), significant productivity gains would be required to offset the increased processing costs.

Inefficiencies in the system have customarily been passed on to the end customer. Improving processing costs can however translate into savings of INR ~300 / MT for end customers while maintaining margins for Coal India.

Cross-subsidy of renewables

A flat indirect tax ("Clean energy cess") is charged by the government on all coal sold to power plants in a bid to promote "cleaner" renewable power. This Cess was introduced in the year 2010 at an effective rate of INR 50 / MT of coal. However, over the past few years, this cess has increased nearly eight-fold to its present rate of INR 400 / MT. This steep increase has eroded the profitability of competitively bid plants while adding to the burden of consumers in case of "cost-plus" / regulated assets. While serving the government objective of disincentivising coal as a fuel, the cess has also artificially brought renewables to parity with conventional generation.

It is estimated that the most recent hike in the Clean energy cess from INR 200 / MT to INR 400 / MT in FY16 has increased power tariffs by 10-12 paisa / unit[5].

Inefficient rail transport

Typically, freight constitutes 20-30 percent of the total landed cost of coal for Thermal Plants. A bulk of domestic coal in India is transported using the railways. Consequently, coal freight is the largest source of revenue for the Indian Railways, accounting for ~33 percent of their total revenue.

However, the freight charges in India are among the highest in the world. For instance, a comparison of indexed freights suggests that rail freight has increased by ~50 percent over the last 5 years while in the same period sea freight has fallen by the same amount (as shown in Exhibit 2.8).

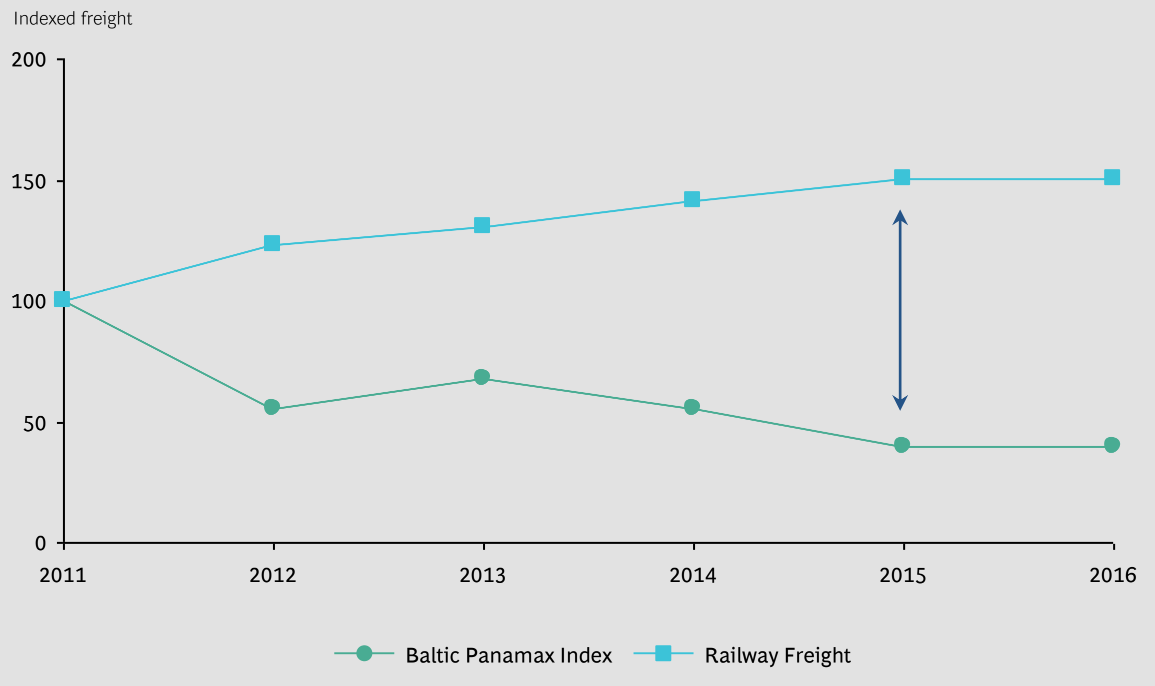
Exhibit 2.7 | Strip Ratio of Coal Across Countries

STRIP RATIO CHANGE ACROSS MINES GLOBALLY

Country	2010	2015	Change %
Australia	5.53	5.44	-2%
United States	2.47	3.09	25%
Indonesia	8.56	7.09	-17%
Colombia	7.17	7.54	5%
South Africa	3.42	3.74	9%
India	1.75	2.25	28%

Sources: AME Research.

EXHIBIT 2.8 | Historical Trend of Indexed Sea and Railway Freight Rates



Sources: Coal India, World Bank, FOIS, Baltic Index.

The system is plagued by multiple inefficiencies:

1. **Inadequate network:** Both freight and passenger trains share the same track capacity[5]

2. **Pricing policy:** Railways hiked freight rates for coal transport between 200-700 KM by 8-14 percent while reducing freight rates by 4-13 percent for transport of coal >700 KM.

   This incentivizes less efficient plants located far from coal sources while dis-incentivizing plants with lower coal logistics costs. While it works for existing plants, this may become a challenge for new generation capacity set-up.

3. **Inefficiency of the railway system in India:**

- The Indian Railways employs 1.3 million people for a network spanning 65,000 km vs. the US railway system requiring only 44,000 people for a comparable length of track
- There are innumerable delays in the execution of projects e.g., for track addition, rolling stock upgradation
- Low Speed of Freight Trains: Trains operate at an average speed of about 20-24 km / hr vs. a benchmark of 60 km / hr
- Cross-subsidy of passenger business: Around 30 percent of railway commercial freight charges are utilized to subsidize passenger fares

In order to make Thermal power more competitive, there is a strong need for reforms to the rail freight network, including re-allocations, enchancing labour productivity and pricing optimization.

Potential to regrade supplied coal

Another typical concern of a number of plants operating on domestic coal has been the issue of Grade slippage: where there is a gap between the quality of coal invoiced & the landed quality of coal received. Grade slippage is typically of the order of 1-2 grades of coal depending on the mine from where coal was sourced and is a loss that most generators have come to accept over time. This artificially inflates the cost of coal procurement, leading to higher tariffs for the end customer. If coal mines were regraded in line with actual quality of coal supply, with stringent norms for rejection of coal shipments basis landed quality of coal (as is the norm for imported shipments), the prospective grade slippage of 1-2 Grades could be averted. This would translate into a cost savings of INR ~170 / MT of coal.

The net effect of these lacunae in the supply chain has been to inflate landed coal prices significantly.

Network of Generating Stations

In addition to the supply challenges discussed above, the power sector as a whole also faces structural supply issues which it hasn't fully overcome. The distribution of generating stations across the country does not correlate to the availability of coal. In fact, as seen in the Exhibits 2.9, 2.10 and 2.11 below, a significant fraction of the total generation of the country is in North India which neither has coal mines nor has preferential access to imported coal through deep draft ports.

Exhibit 2.9 shows that the major chunk of India's 194 GW coal-based generation capacity is set up in the West (70 GW), while the East has only 29 GW of installed capacity, generated from 40 thermal plants set up in the region. This is despite the fact that the East is the leading producer of coal in the country with an annual output of almost ~283 million MT of coal (as shown in Exhibit 2.10). However, North India continues to generate ~52 GW of power, with a cumulative production of only 13 million MT of coal pa. and with no access to ports.

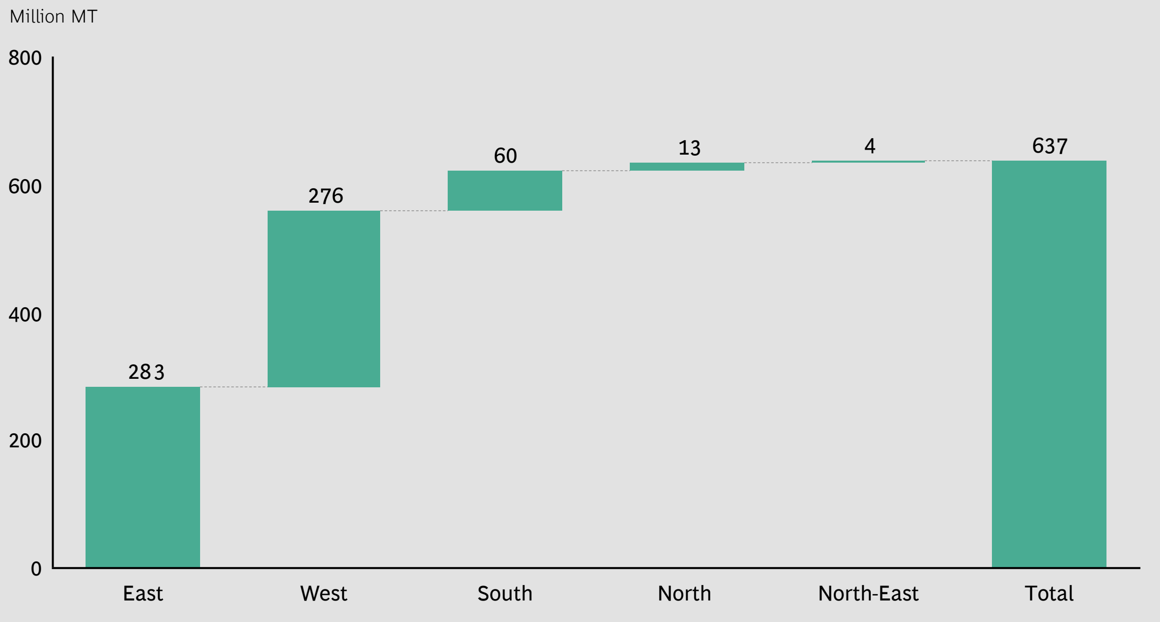
A relic of a time prior to an interconnected grid, the current network of plants is highly sub-optimal (as shown in Exhibit 2.11): these Plants located far inland / close to the point of demand, incur significant logistics costs in transporting coal from the mine pithead / port of unloading.

With a majority of these plants being "cost-plus' regulated assets, it is the end customer that once again bears the cost of this inefficiency.

Exhibit 2.9 | Installed Generation Capacity in India by Region

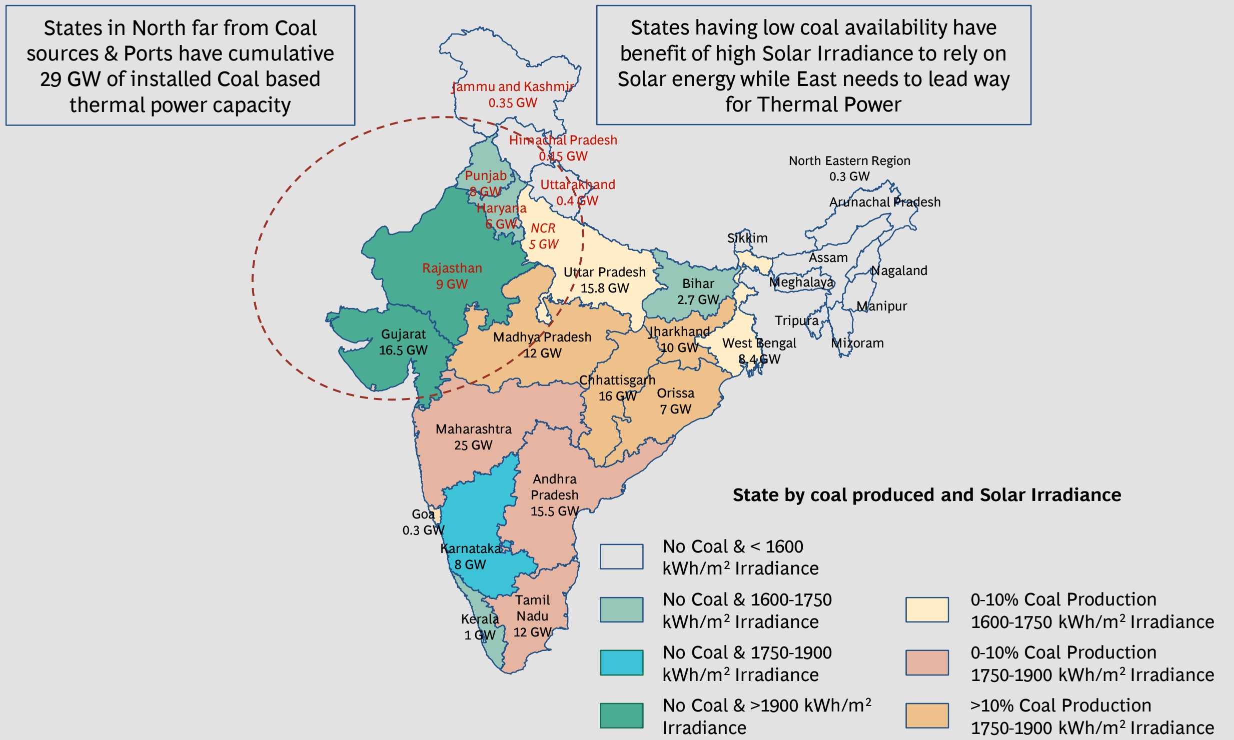
Source: CEA.

Exhibit 2.10 | Coal Production in India by Region



Source: Ministry of Statistics and Programme Implementation, Government of India.

Exhibit 2.11 | Coal Availability and Irradiance Intensity in India



Source: Irradiation data from Solar GIS.
Note: % of Coal produced in state calculated on total domestic coal production per annum FY16.

What is however interesting to note is the complementary nature of Solar and Coal power. Locations with low coal availability also seem to typically have higher solar irradiation (e.g., Rajasthan). With careful planning and augmentation to the transmission capacity across the country, the blueprint for an efficient network of coal & renewable generating stations can be set up to optimize tariff costs to procurers.

Execution Delays

To further compound the supply and demand challenges faced by developers today, a large number of projects have run into execution challenges leading to time delays and cost overruns. There has been a significant underestimation of execution challenges by developers—projects remain stranded due to procedural delays in land acquisition.

Stranded Assets

The net impact of the demand and supply gaps has been the gradual increase in the number of stranded assets.

Private participation in Indian power sector has been a story of starts and stops. A combination of slow demand growth, business environment problems, policy inaction and developer aggression has led to a rise in stranded assets in the sector.

Nearly 50 GW of the total installed power capacity of India is stranded. There are over 34 stressed thermal power plants in India whose total debt exposure is around INR 1.77 lakh crore. In fact, after steel, NPAs in the power sector are highest, making up to 12 percent out of the total bad debts of India INR ~14 lakh crore. A total of 17 under-construction thermal power projects aggregating to a capacity of 18,420 MW were reported as stalled due to financial problems of the developers.

A comparison with steel, the other major contributor to stressed assets in the country, helps identify and contrast the problems facing the Indian power sector:

- While demand in steel has taken a hit due to Chinese overcapacity, India's power sector demand remains localized but has failed to grow at the expected pace
- While steel prices remain strongly linked to market, PPAs have failed to provide the revenue guarantee to power plants

NOTES:
1. 2017 Energy Sector set for a bull run, Infraline.
2. Current Worries, CRISIL.
3. BCG analysis
4. AME research
5. Infrastructure in Logistics, EnRoute.

FUTURE OUTLOOK OF COAL-BASED POWER GENERATION

As explored above, the net outcome of the challenges faced by the power sector today has been to put generation assets increasingly at the risk of being stranded. In addition to the short term & structural issues faced by the coal-based power generation sector today, the lack of policy support and growing competition from renewables pose a major threat to the sector with the potential to derail future investments in the sector.

Policy Interventions Focus on Renewable Sector

Over the past few years, Government policy has strongly supported the creation of renewable capacity. In-line with global expectations to reduce emissions, the Indian Govt. has set an ambitious target of achieving 175 GW installed renewable energy capacity by 2022. In solar energy as well, the total installed capacity is slated to grow to 5x its 2016 value, which is even more aggressive than scenarios predicted by IEA (as shown in Exhibit 3.1).

Consequently, policy interventions have largely focused on enabling the renewable sector.

Govt. policy directly and indirectly subsidizes renewable generation, which in turn decreases the relative competitiveness of Conventional generation:

1. RPO / RGO obligations compel DISCOMs to procure a certain fraction of their demand from renewable sources, irrespective of where such a source would be positioned on the Merit Order for the DISCOM

2. No import duty is imposed on critical imports for the Solar sector: such as wafers, cells and modules

3. EPC projects in Solar can avail of a preferential taxation regime of 5 percent (even under GST) in comparison to Thermal projects where taxation on EPC projects can be as high as 18 percent

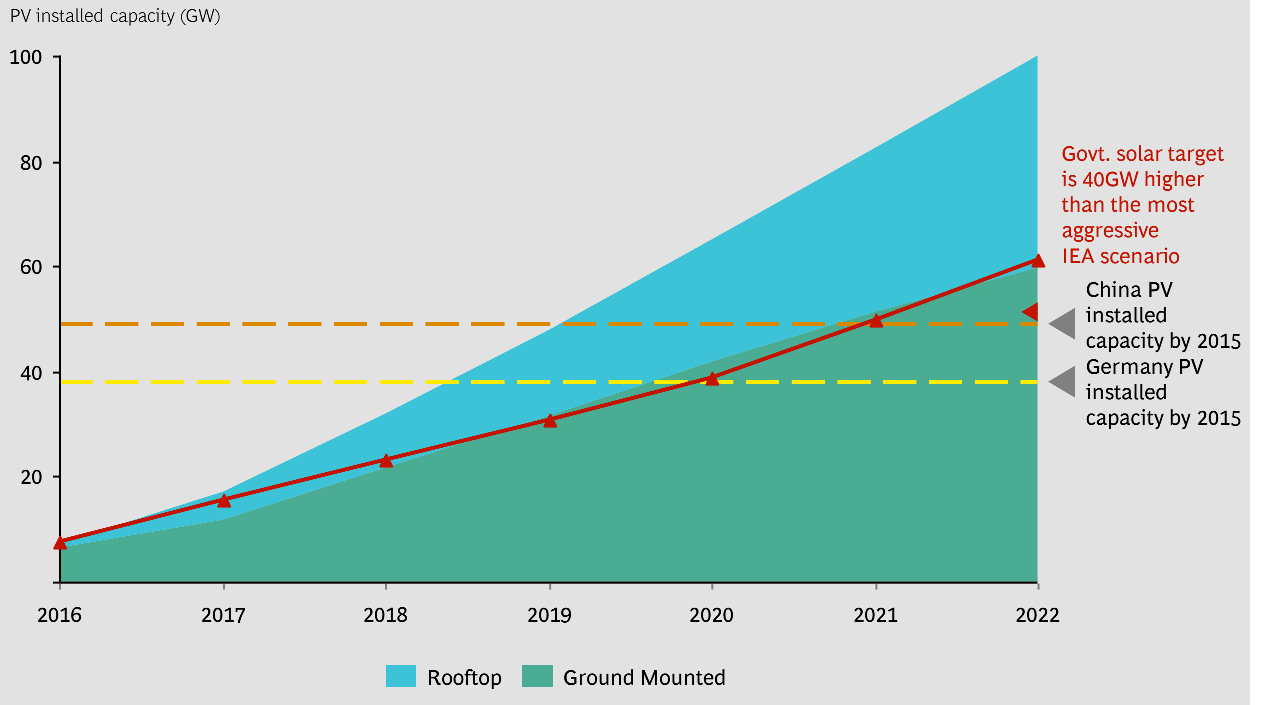
4. Renewable stations (both wind & Solar) can avail of Accelerated Depreciation for taxation purposes

5. DISCOMs need not pay transmission charges on inter-state transmission of solar power

6. In addition to direct power sales, Renewable-based generation also enjoys the benefit of sale of Renewable energy certificates

7. Limitations on the storage capacity for Solar and Wind power mandate the scheduling of power by a DISCOM to renewable players first, prior to schedul-

EXHIBIT 3.1 | Installed Capacity Projections for Solar



Sources: MNRE, IEA World Energy Outlook 2015, Bridge to India report, BCG analysis.

ing the remainder to other conventional power generating stations. As a result, coal-generating stations in general effectively occupy a lower position on the merit order for DISCOMs

8. Clean energy cess charged on coal purchase for power consumption has doubled year-on-year since 2015: increasing the cost of Thermal power generation & cross-subsidizing renewable generation

9. The tripartite agreement between the Government of India, State Governments and RBI to support SECI has improved its credit rating, which has in turn led to the lowering of interest cost for Solar developers due to de-risking of the Solar business as a whole

While support for renewable generation is critical to ensure that India meets its 2022 renew¬able targets, policy support is also required for conventional generation assets that would potentially be impacted by the push for renewables so that both contribute simultaneously in ensuring the stability of the grid.

Fuel, Regulatory and Project Risks

Unlike Renewable sources of energy, conventional generating stations face tremendous fuel risk: both in terms of availability of supply & in terms of price. Plants based on domestic coal are over-dependent on the monopoly of Coal India for their supply while imported coal-based plants are vulnerable to significant fuel price, regulatory and country risks.

Furthermore, owing to the timelines involved in the setting up of Thermal projects (with projects taking anywhere from 2-3 years to be commissioned), these projects also face significant project risk from change in Government policy. Interest and exchange rate risk also remain a concern for investors availing of debt from international markets.

Renewable Grid Parity

Another important threat comes from the renewables sector: from the dramatically falling costs (and consequently lower levelized tariffs) of solar energy. Solar has nearly reached tariff parity with thermal generation driven on the back of cheaper imports from China. As described earlier, these renewable resources are in direct competition (at least in the short term) for the same end customer demand.

The Government is also planning on a dedicated Green energy corridor, that prioritizes Solar energy over Thermal.

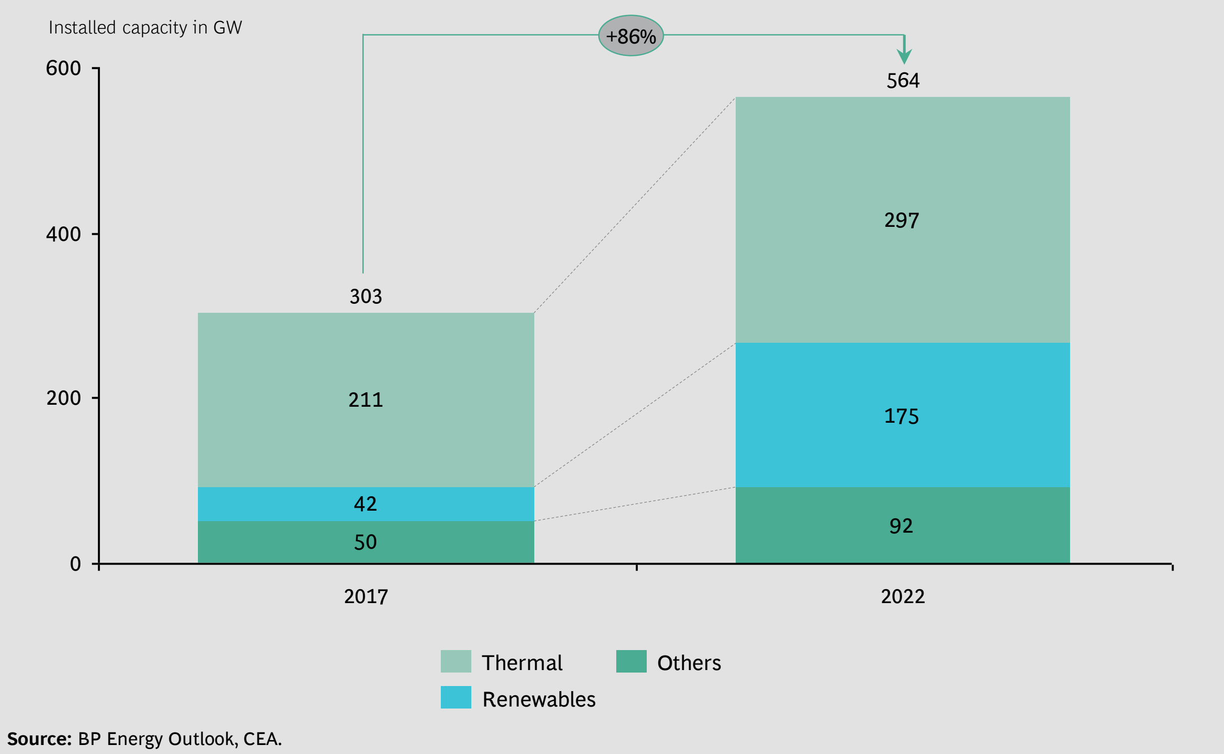
Limited Investment Opportunities

Only around 86 GW of capacity addition in the next 5 years would need to come from coal power plants (as shown in Exhibit 3.2): a bulk of which (~50 GW) is already in various stages of construction. With the aggressive push for renewable capacity addition, this ensures that few coal-based power plants need be set up in the country (at least till 2022). Limited opportunities hence remain for green-field investment in the sector. CEA has gone so far as to say that India does not need more coal-based capacity addition till 2022.

With non-thermal capacities coming on stream over the next 5 years, existing coal-based thermal power plants face the prospect of continued low utilization of their assets (with numbers as low as 48 percent by 2022[1]), As a consequence, brown-field opportunities in the sector also remain limited.

NOTE:
1. 2017 Energy Sector set for a bull run, Infraline.

EXHIBIT 3.2 | Projected Energy Mix of India by 2022



Source: BP Energy Outlook, CEA.

LEARNINGS FROM MATURE RENEWABLE ECONOMIES

COAL IS HERE TO STAY

GIVEN THE CURRENT AND future challenges to coal-based Generation, a question of great import for Generators & DISCOMs alike is whether coal as a source of power would be relevant 5-10 years in the future? Given the push for Renewables and the associated investor interest for Solar and wind energy, is there a role or a niche present where coal-based plants may operate?

India's renewable growth is slated to grow dramatically in the near future: a growth which derived primarily from solar and wind—projected to contribute approximately 57 percent and 35 percent respectively to the total renewable energy generation in 2022. Renewable energy target of 175 GW would meet 35 percent of India's total requirement of 490 GW by 2022.

This dependence on solar and wind is however not without its own share of structural problems. Foremost among them is the issue of fluctuations in load.

Fluctuations on seasonal and weather patterns are common to both solar and wind, however day-night fluctuations are a challenge specific to Solar PV. A detailed view of these fluctuations is shown in Exhibit 4.1 below. While some of these fluctuations are cyclical and predictable, others are tough to predict, thus endangering grid stability.

As the share of solar energy in the total energy portfolio increases, greater will be the impact of the daily generation cycle of Solar energy. This would require seamless grid load transition between renewable and conventional energy going forward[1].

The state of California, USA provides a model on what could be the potential impact on grid stability with increased dependence on renewables. The State was in the process of a major shift towards renewables, when the Grid authorities noticed an interesting pattern in the profile of Solar Load across the day: a pattern which has now been popularly christened as a 'Duck curve' (because of its shape).

The bulk of the Solar generation for the State of California occurred during the low demand period of the day. The blue line in the curve in (as shown in Exhibit 4.2) shows the usual electricity demand pattern, the dark green line shows the profile of solar load, while the light green line shows the difference between the two. As seen in (Exhibit 4.2), the solar load peaks in the morning and in the afternoon and gradually falls off at all other times. The greater the dependence of a grid on solar power, the greater the distortion to its load curve during the day owing to this fluctuation in supply. The gap between the two lines shows the net load gap that had to be bridged by conventional sources of energy.

EXHIBIT 4.1 | Fluctuation Patterns in Wind and Solar Based Generation

FLUCTUATION PATTERN | **IMPLICATION FOR COMPENSATION**

1. **Day-night fluctuations (PV only)[1]**

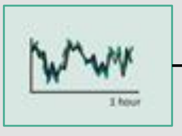
2. **Annual or seasonal fluctuations (climate) (PV & wind)**

→ **Cyclical, predictable**

- Recurring patterns with specific regional variations
- Partially correlated with variations in load; fluctuating renewables' feed-in actually reduces load fluctuations
  - The optimum solution is to balance residual load (that is, the energy generated from conventional sources) rather than feed-in from fluctuating renewables

3. **Medium-team fluctuations (weather) (wind only)[2]**

4. **Short-term fluctuations (forecast error) (wind only)[3]**

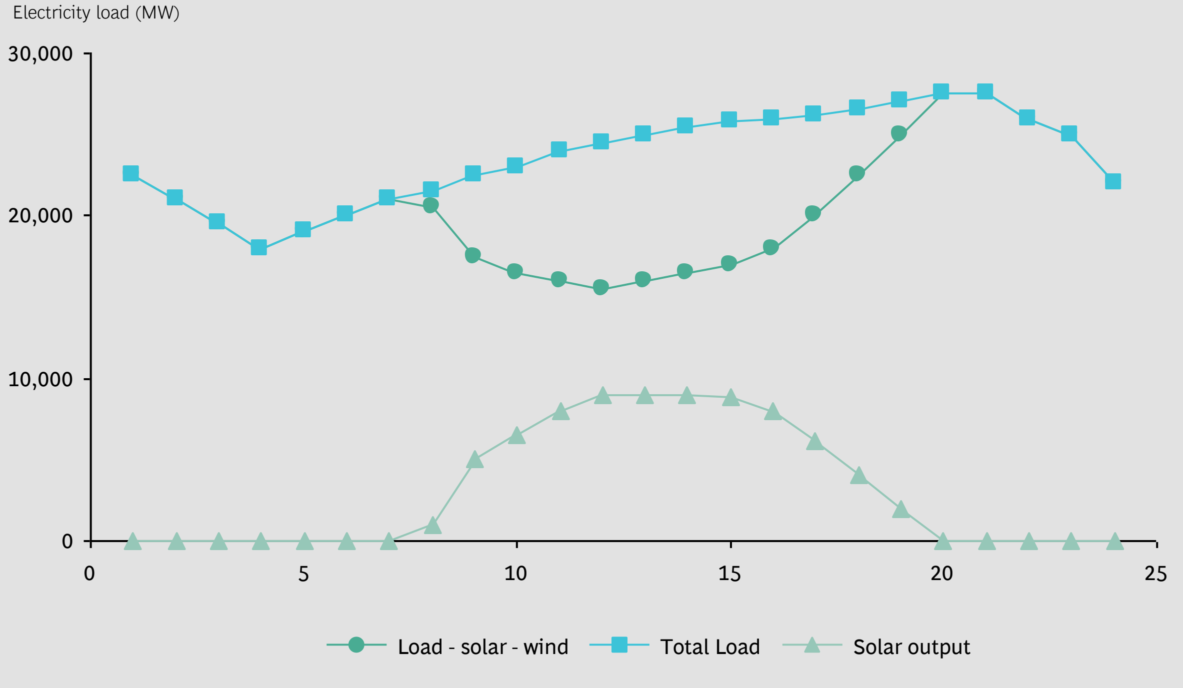


→ **Erratic, unpredictable**

- Scale directly with installed capacity of fluctuating renewables
- Improvements through better forecasting are possible; yet the growth of generation clusters (offshore) will make forecasting increasingly difficult
  - There is a direct need to balance fluctuating renewables' feed-in to ensure the security of the overall energy supply

Source: BCG analysis.
[1]Not relevant for wind except for localized phenomena, which were not considered; PV = photovoltaic.
[2]When the study was conducted, no feed-in data for PV were available.
[3]Related to 24-hour forecasts for wind energy. When the study was conducted, no forecast or feed-in data for PV were available.

EXHIBIT 4.2 | California "Duck Curve"



Sources: Economic Times, California ISO.

Only conventional sources such as coal have the flexibility to ramp up from about 60 percent of the full load to as much as 100 percent of the full load over the course of the day to accommodate the fluctuating demand.

This inconsistency in energy availability from renewables stresses the need for flexibility in the grid. Electricity generation from these conventional plants cannot be fully replaced as they provide a buffer against the fluctuations, thereby stabilizing the grid.

Thus, while the impact of the duck curve can be mitigated to a limited extent by resorting to peak load pricing to shift demand to other parts of the day, conventional sources of generation will continue to remain a crucial part of the power ecosystem.

However, depending on specific operating conditions, even coal plants (as they are today) might find it difficult to rapidly ramp up over the course of a few hours to meet the deficit created by drop in solar load. This is especially true if plants need to be frequently shut-down & started up to match the load curve, as the associated costs would have an adverse impact on plant profitability. To put things in perspective, in 2016 the ramp-up required by sources other than wind and solar over a span of 3 hours in the evening was about 10 GW. Thus, conventional sources are currently not fully equipped to handle this flexibility requirement. To tackle these challenges, a mix of low-cost, speedy solutions and long-term initiatives would be required to improve the flexibility of the grid. An application of this combined focus on renewables and coal can be seen in Germany's energy generation system. Germany is on track to expand its renewable generation to meet 40-45 percent of its total demand by 2025. However, at the same time, it has a surplus of conventional generation capacity, until about 2018. This results in high grid stability as Germany ranks among the most reliable power supply systems in the world. Average annual downtime was just about 16 minutes (in 2013), which was one of the lowest in Europe and in the world.

NOTE:
1. BCG Perspectives

WAY FORWARD

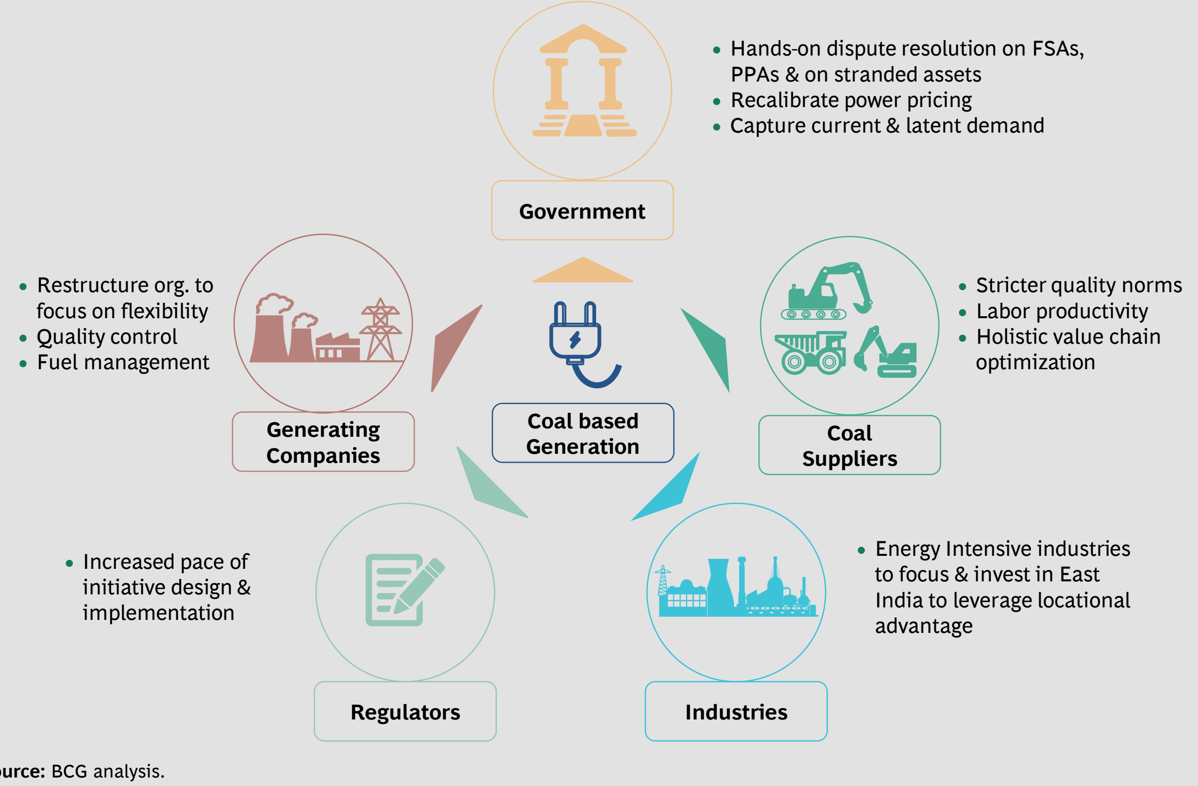
INTERVENTIONS / CHANGES NEEDED TO ENSURE SUSTAINABILITY OF CONVENTIONAL GENERATION

With the shift in the role of coal-based generation, it is imperative that a framework be developed to support Conventional GenCos in the transition while not compromising on the country's renewable aspirations. Thus, Stakeholder-wise interventions have been recommended to ensure sustainability of coal generation in India (as shown in Exhibit 5.1).

1. **Fuel Suppliers:**

- Grade of coal supplied remains of critical interest to plants: renewed efforts from

Exhibit 5.1 | Recommendations for Five Key Stakeholders of Coal-based Generation



Source: BCG analysis.

Coal India to regrade mines periodically combined with stricter rejection norms at the GenCo would ensure greater transparency in the supply chain and reduce grade slippage

- Productivity increase: Coal India should work towards improving labour productivity in line with best-in-class mines around the world through investment in Capital equipment

- CIL should support GenCos in Power generation and in unlocking efficiencies in the value chain through optimizing type of coal used

2. **Government:** A hands-on approach is needed from the government to resolve disputes related to FSAs, PPAs or land acquisition for stranded assets. Additionally, measures need to be taken to cure ailing DISCOMs: either by privatization or by recalibrating the price of power to consumers to ensure financial viability for ailing DISCOMs. This will in turn help capture the current and latent demand.

   The opening up of the mining sector also promises to help in the development of the sector as a whole with the Government planning to allow commercial mining in future coal block auctions.

3. **Regulators:** Increase the pace of resolutions, approvals, design and enforcement of incentive mechanisms etc. within the purview of the law and regulation

4. **Generating Companies:** Rework internal processes, organization structures and investments to incentivize flexibility in plant operations going ahead and efficiency to keep pace with the fall in renewable tariffs. Additionally, focus on quality control and tighter fuel management

5. **Industry:** East promises ample opportunities to the energy intensive industries with its strategic locational advantage close to coal mines. Energy intensive industries are typically reliant on captive power generation to meet their needs. Given that power would constitute a significant fraction of input costs for such industries, locating integrated captive generating plants & manufacturing units close to source of fuel supply would significantly bring down total cost of production. This calls for more industry investment and action in the Eastern region.

FOR FURTHER READING

The Boston Consulting Group published other reports and articles on related topics that may be of interest to senior executives. Recent examples include:

New Paths to Productivity in Power Generation
An article by The Boston Consulting Group, August 2017

Rewiring Utilities for the Power Market of the Future
A focus by The Boston Consulting Group, October 2016

Optimizing Grids to Meet New Demands on Power Systems
An article by The Boston Consulting Group, September 2016

Is COP21 a Win for Europe's Power Producers?
An article by The Boston Consulting Group, August 2016

Managing in Turbulent Times: Europe's Power-Generation Market
An article by The Boston Consulting Group, September 2014

NOTE TO THE READER

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