

Coal Requirement in 2020: A Bottom-up Analysis

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List of abbreviations

AT&C	Aggregate Technical and Commercial (losses)
BU	Billion Units (kWh)
CAGR	Compounded Annual Growth Rate
CEA	Central Electricity Authority
CIL	Coal India Limited
COP21	Convention of Parties 21 (Paris Conference on Climate Change)
CSE	Centre for Science and Environment
CUF	Capacity Utilisation Factor
FSA	Fuel Supply Agreement
FY	Fiscal Year
GCV	Gross Calorific value
GDP	Gross Domestic Product
GoAP	Government of Andhra Pradesh
GoI	Government of India
GW	Gigawatt
IGEN	Indo-German Energy Program
INDC	Intended Nationally Determined Contributions
kWh	kilowatt-hour
MNRE	Ministry of New and Renewable Energy
MoC	Ministry of Coal
MoP	Ministry of Power
MT	Million Tonnes
PLF	Plant Load Factor
PTI	Press Trust of India
RE	Renewable Energy
ROI	Return on Investment
SCCL	Singareni Collieries Company Limited
UMPP	Ultra Mega Power Projects
YOY	Year-On-Year

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Key findings

- India is heavily dependent on coal based power for its electricity needs, 79 per cent of total electricity generation is coal/thermal based. This is not expected to change drastically in the near future.
- Thermal power generation consumes around 76 per cent of total coal available in the country (imports included). Given its high coal consumption, power sector has a disproportionate impact on future coal demand.
- Imported coal constituted 26 per cent of total coal supply in FY'14-15 (212 MT of the total supply of 820.3 MT), however, the imports were 6 per cent lower (than 212 MT) in FY'15-16. Given that boiler technology locks in to a specific type of coal (imports/blending inclusive), it is unlikely that imports will ever be zero.
- The ambitious target of producing 1.5 billion tonnes of domestic coal is too high, vis-a-vis the expected increase in coal requirement(s) by 2020. The actual coal requirements are expected to be (*at a maximum*) around 1.2 billion tonnes in 2020 (subject to certain optimistic assumptions of growth in demand).
- In addition to GDP growth rates, the Renewable Energy capacity targets of 175 GW by 2022 could also impact coal demand in 2020, pushing it further down, displacing thermal generated kWh.
- Huge thermal power capacities are expected online by 2020. This will impact PLFs, with economic and technical implications for the new capacities. And, if financial reforms in the distribution companies do not work as expected, there could be stressed assets as well, impacting liquidity in the banking sector.
- Railways capacity augmentation is a related investment within the same timeframe (till 2020) to enable actual coal offtake for increased mining capacity. To enable capacity augmentation, it is essential to look holistically at the total capital requirements for both these sectors simultaneously.

1 Summary

1.1 Coal targets were purposely ambitious, but may be unnecessarily so

In FY'14-15, the government announced an ambitious plan to produce 1.5 billion tonnes of coal domestically by 2020, an annual growth of almost 20 per cent. The announcement came at the back of the then chronic shortfall of coal. However, by the end of FY'15-16 India's coal shortfall ended. In fact, power plants—which are the largest users of coal—reported an oversupply of coal, a situation mirrored in terms of power, with *plant capacity* growth outstripping power demand growth.

The 1.5-billion tonne target was split between Coal India Limited (CIL) (and other smaller PSU producers) producing 1,000 MT and private (captive) producers contributing the remaining 500 MT by 2020. For the given target, we have envisioned three sets of growth rates (compounded annual growth rates, or CAGRs)

Estimated requirements of coal in 2020:

- *Scenario 1 – upper bound for coal requirement, based upon power plant capacity:* Non-power sector demand was extrapolated based on GDP and elasticity assumptions,¹ and power demand was bounded based on upcoming thermal power capacity (examining all plants under construction, their locations, technology, and status, assuming a plant load factor (PLF) same as in FY'14-15.
- *Scenario 2 – Offtake based on power demand:* Keeping non-power demand the same as scenario 1, a detailed power demand calculation² for 2020 led to coal demand estimates based on assumptions on share of thermal generation.

The target and estimates however, do not align, as shown in Table 1

¹ Assumptions for non-power sector include the following: A base assumptions of 8 per cent GDP growth, respective sectoral GDP elasticities and continued imports proportionate to imports in the base year FY'14-15.

² Base power demand calculations assume: additional demand linked to GDP, zero load-shedding by 2020, "meaningful" electrification to hitherto unconnected rural consumers and reduction in technical losses.

Targets for coal production in 2020		FY'14-15 [MT]	2020 [MT]	CAGR
Coal requirements (targeted)	Total domestic coal	609	1500	19.8%
Public sector growth required	All public (CIL + Others, proportional)	567	1000	12%
Private sector growth required	Private	45	500	61%
Scenarios for coal requirements in 2020		FY'14-15 [MT]	2020 [MT]	CAGR
Scenario 1: thermal power <i>plant</i> based coal requirements (keeping PLFs as FY'14-15, ~ 64%)	Domestic coal	609	996	10.3%
	Total coal	820	1311	9.8%
Scenario 2: Power <i>demand</i> based coal requirements (more realistic)	Domestic coal	609	929	8.8%
	Total coal	820	1228	8.4%

Table 1: Summary of coal demand growth rates for various scenarios (in million tonnes). *These have base assumptions of 8 per cent GDP growth, modest RE growth, and continued imports due to economics and power plant technology choices (plus imports of coking coal). Note that one tonne of imported coal isn't the same as one tonne of domestic coal due to different quality of coal (heating value).*

1.2 2020 domestic coal requirements to range between 900 and 1,200 MT (based heavily on electricity demand scenarios and import choices)

Table 1 shows the base calculations based on assumptions. The capacity based analysis is an intellectual exercise to show an upper bound on the coal required. Given demand-based projections are lower, these become the bottleneck and provide a more realistic range of coal requirements. If one ignores demand for power, the implication would be further "overcapacity" of power plants, and a fall in PLFs.

All calculations are based on assumptions, and sensitivity analysis indicates what factors matter, and by how much. High and Low demand scenarios indicate a range as shown in

Table 2, still lower than the nominal target of 1,500 MT. The 'High coal' scenario is optimistic and assumes zero imports of thermal coal (coking coal imports, however, are assumed to continue), a high GDP growth of 8 per cent, 100 per cent electrification with zero load-shedding, and a modest

growth of Renewable Energy (with no additional displacement of coal share versus today, which would undershoot the target of 175 GW RE). The 'Low coal' scenario assumes a partial improvement in supply quality with imports in the same proportion as were in FY'14-15.

Scenario	Total coal required (MT)	Domestic supply (MT)	Total imports (MT)	Comments
Base	1228	929	299	Imports proportionate to existing ratio
High coal	1291	1225	67	End all imports except coking coal
Low coal	1139	868	272	Conditional upon demand side limitations and continued imports

Table 2: Coal requirements for different scenarios (based on power sector demand overriding power plant capacity availability). *Low coal scenario assumes slightly lower GDP growth (7.5 per cent), imports remain in the same proportion to the domestic supply as FY'14-15, 50 per cent electrification of hitherto un-electrified households (slight but incomplete improvement), and a 3 per cent power supply shortfall (versus 3.6 per cent in FY'14-15) and renewable share of power generated is 10.8 per cent.*

1.3 The hand for 2020 has already been dealt: Not much flexibility in displacing imports for existing/planned power plants as targeted, and high RE targets

Almost 76 per cent of coal is consumed by the power sector, and 79 per cent of electricity generated from thermal power plants. Given that coal power plants take years to materialise, we can assume that plants in 2020 are either under operation or already planned or under construction. Given that boiler technology requires specific coal quality—sometimes fully imported, other times with blending—it is unlikely that imports will be zero by 2020 or even later. The report details how coal requirements were calculated across plants, factoring in their location, technology, status, etc.

We find that the number of coal power plants under advanced planning or construction is far higher than likely required. This indicates that overall system PLFs will fall even further, or place financial stress on plants. As per Central Electricity Authority calculations and planning estimates, the earlier high PLFs of upwards of 73 per cent are very difficult, if not impossible, to realise in future.

Economics would warrant existing plants be utilised to the highest level possible (high PLFs), but the power position in India of surplus at some times in a day reinforces the challenge of peaking power (mostly in the evening). This indicates that coal-based plants, which are baseload plants,

aren't the only need for India's power sector, and neither is solar power. In addition to not meeting the peak demand, RE also places other system burdens, such as high ramping requirements in the evening (the so-termed "duck curve"). An "optimal" portfolio of power plants is assumption-driven based on the objective function: lowest cost vs. energy security vs. environmental improvement etc.

As an example of sensitivity analysis, Figure 1 shows the impact of different RE capacities on coal demand. This assumes a fixed (exogenous) demand for power, and a 19 per cent PLF for RE. The impact of very ambitious RE targets is modest, in the tens of millions of tonnes of coal per annum.

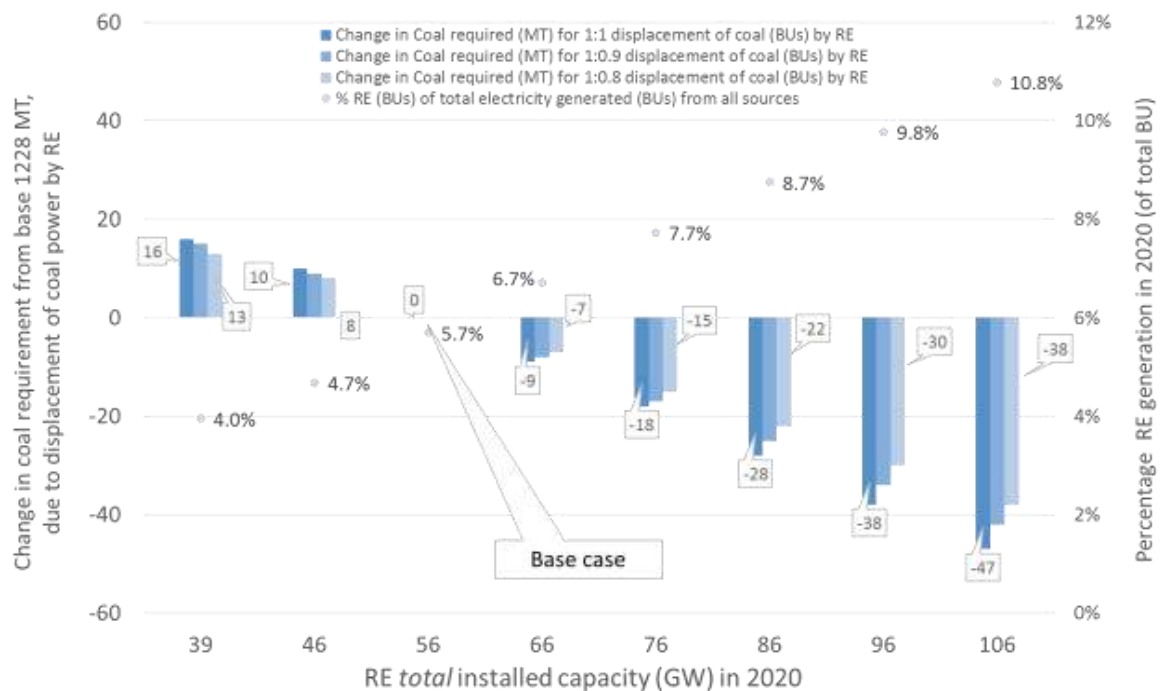


Figure 1: Impact of RE displacing coal demand in 2020 based upon various RE capacity achievements by 2020. The 2022 target of 175 GW implies the need to reach 106 GW by 2020, which would increase the RE share of total projected electricity (BUs) to 10.8 per cent. Any level of RE share growth (or fall) could displace coal BUs at varying levels, from 1:1 to perhaps less (assuming other generation also backs down in favor of RE).

GDP growth rates and future electricity demand are among the key variables or wild cards that can likely pull down the coal requirement compared to the base case assumption of 8 per cent GDP growth and 100 per cent electrification, zero load-shedding, etc. Figure 2 shows the impact of GDP on demand from not just power sector growth but non-power sector growth like for cement and steel industries etc. A 1 per cent (absolute) reduction in anticipated GDP growth rate reduces the coal requirement in 2020 by about ~4 per cent.

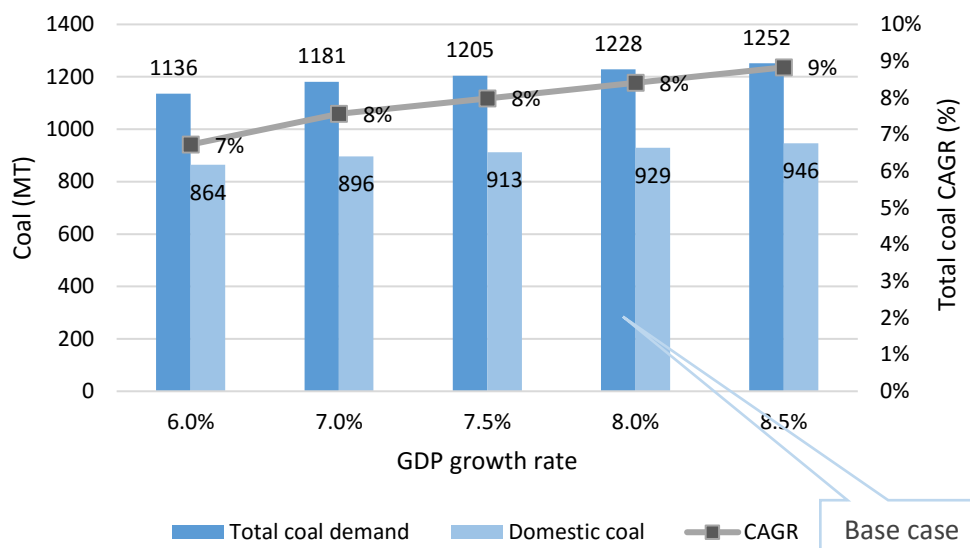


Figure 2: Impact of GDP on coal requirements.

Power demand is a major factor for India's coal requirement. There are multiple future electricity demand exercises conducted by various organisations, including by the Central Electricity Authority (CEA). In one such exercise, CEA found that the combination of rapid capacity growth in the last few years and modest demand growth means a fall in power plant PLFs and/or stranded (if not abandoned) capacity. One possibility is system equilibrium that encourages retirement of older coal plants, on environmental and/or efficiency grounds.

Figure 3 shows the complexity of calculating demand elasticity with GDP. Higher GDP growth rates indicate a possible lower elasticity, which also cannot be separated from issues of autocorrelation (prior year lows/highs indicate compensation the next year), the impact of the monsoon, not to mention targeted growth of manufacturing.

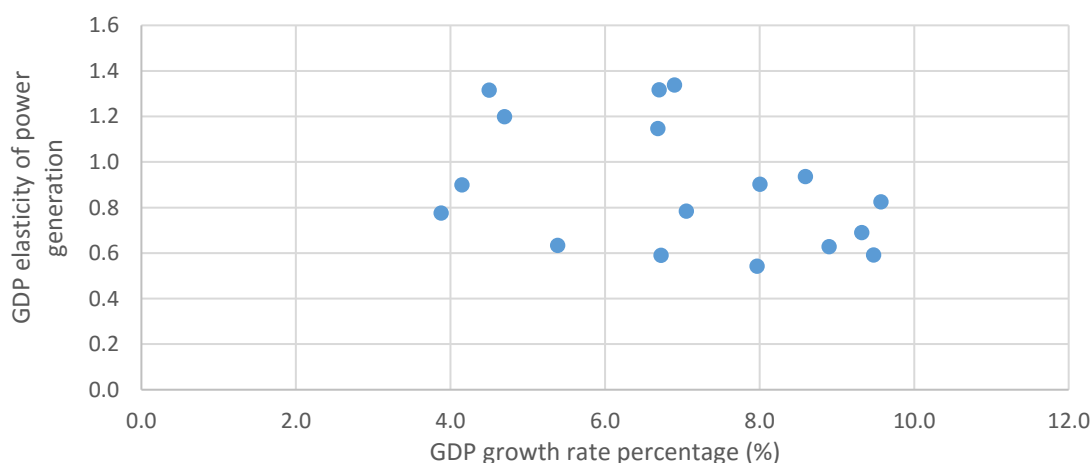


Figure 3: GDP elasticity of power generation vs GDP growth rate (1998 – 2015). This is based on MoP/CEA data for generation (BU) and Ministry of Finance data for GDP.

Other wild cards (unknowns) that could impact coal demand in the future include:

- Imports for both coal and end-products such as steel. These depend on macroeconomic conditions, global prices, etc.

- Growth (or not) of alternative sources of power
- Demand from power distribution companies and consumers. Factors other than GDP based, reforms such as UDAY should help improve the demand for power, but some of this is already captured in the base assumptions on power demand.
- Logistics, especially railways, can be a bottleneck. Also, the costs involved can determine if end-users want to use domestic versus imported coal.

Ultimately, the calculations are for the demand of coal, which still leaves enormous challenges for its supply (i.e., mining). Even the lowered estimates for demand, far lower than 1,500 MT, still leave pressure to perform. Given that the private/captive sector has dramatically higher growth targets for mining and has not grown anywhere near envisaged through FY'15-16, this still leaves enormous pressure on Coal India Limited to grow output by 2020.

2 Introduction and objectives

In this report, we aim to examine the demand for coal in India in 2020 (using FY'14-15 as a base year), focusing on domestic coal production. Coal is predominantly used in power production, and hence answering this question requires a deep dive into (1) Demand for power; (2) Alternatives for power generation, especially Renewable Energy (RE), which has ambitious growth targets in the short term; and (3) ability to produce coal-based power (looking at virtually all the power plants under construction/planned, examining their location, technology, status of clearances, etc.)

Clearly, this is not an easy exercise. First of all, there are inter-relationships between variables, and hence the holistic look at this topic (one cannot do simple extrapolations only). Second, there is enormous uncertainty, even in just a few years (forget a more complex exercise such as modelling for 2030, the year for the carbon commitments for Paris COP21, through India's Intended Nationally Determined Contribution (INDC)). Therefore, we apply not just wide sensitivity analysis, but also have released the model³ used, so that analysts/scholars/decision-makers can modify key assumptions to visualise its impacts.

³ The model is available online at the Brookings India website:
<http://www.brookings.in/coal-requirement-in-2020-a-bottom-up-analysis/>

3 Coal in India

3.1 Coal demand and availability

Coal contributed to around 79 per cent of the total generated electricity in India in FY'14-15. The total gross power generation stood at 1,110.2 BU⁴ (CEA, CEA Monthly Executive Summary Power Sector, April, 2015) till 31 March 2015, of which 1,048.67 BU was from non-RE (mostly coal), while 61.78 BU was from RE⁵. Preliminary data till 31 March 2016 indicates that total generation has increased by 5.7 per cent YoY, the comparable value in FY'15-16 was 1,173.2 BU total, with 1,107.38 BU from non-RE sources and 65.78 BU from RE (CEA, CEA Monthly Executive Summary Power Sector, March, 2016) (CEA, CEA Monthly Executive Summary Power Sector, April, 2016). Considering the high share of coal-powered electricity, it is safe to say that India is heavily dependent on coal for its electricity requirements and, as we shall see later in this report, most of the coal used is indigenous.

In addition to its use for electricity generation, coal is also the base fuel for many other industries such as iron and steel, aluminium, and cement. The role of coal in powering multiple segments of India's industry puts it firmly in the vanguard for achieving India's economic growth potential.

In the above context, the total demand for coal in India for FY'14-15 was ~787 MT (Ministry of Coal, 2014-15), whereas the total indigenous supply of coal was in the range of ~608 MT, an additional ~212 MT was imported in FY'14-15. Imported coal accounted for ~26 per cent of all available⁶ in India in FY'14-15, despite India holding the fifth-largest coal reserve (Technology, 2014) in the world, seemingly sufficient for many decades of consumption.

3.2 Quality and quantity constraints of Indian coal types

Indian coal has a lower average GCV (gross calorific value) ~4,000 kcal/kg and a higher average ash content ~34 per cent compared with international coal⁷. High ash content reduces the amount of heat available for use per tonne coal input⁸. This also has negative economic implications if high ash coal is transported long distances and also causes pollution, as combusted coal inevitably releases some ash into the environment.

Imports from foreign destinations, mainly Indonesia (only steam/thermal coal) and Australia (largely coking coal) are one way of compensating for lower heat value of Indian coal, on a joule

⁴ Billion Units (BU), or Billion kilowatt-hours (kWh). This generation is gross as from utilities and grid connected, and excludes captive or back-up power.

⁵ RE as defined by India is "New Renewables" such as solar, wind, micro-hydro, and excludes traditional hydropower.

⁶ Coal availability and consumption are separate, all coal that is mined/imported may not be consumed in the same year as some is stockpiled at either the pithead or the plant stockyard. However, while recording the total available coal, all coal that enters the system is recorded. The authors recognize this nuance for accounting of coal in future, but given the lower level of stockpiles in FY'14-15, have not applied it for the base year calculations. However, in 2015-16, some of the "consumption" by a sector can include measurable stockpiles. And, this would also impact the specific coal consumption calculations.

⁷ Indonesian coal has ash content between 5 and 12 per cent (Indonesia, Rich coal, 2015) and Australian coal between 8 per cent to 20 per cent (Australia, Rail Page, 2015)

⁸ As opposed to imported coals which has higher average GCVs and lower average ash content resulting in higher available heat per tonne.

per kg basis, and this is one reason, in addition to using solely imported coal, that a number of power plants import coal to blend with domestic coal. Also, until recently, there was a restriction on the coal import with ash content higher than 12 per cent, which was recently amended (PTI, 2015) for the UMPPs (Ultra Mega Power Projects) to introduce competition by opening up imports from countries other than Indonesia⁹.

India has *insufficient* coking coal reserves, which was why only 31 per cent of the total coking coal demand in FY 2015 (~56 MT) was indigenously available. Coking coal is required for steel making, through the blast furnace route. With increasing urbanisation, it is anticipated that there would be an increased requirement of steel in the future (for construction and also white goods and other products). However, insufficient domestic reserves of coking coal necessitate imports. This is however, before considering macro demand issues for finished products, for example; Chinese overcapacity of steel coupled with a slowdown in domestic consumption leading to surplus capacity of finished steel in China, which may then be imported by India regardless of alleged dumping. Table 3 captures the increase in coking coal imports between FY'11-12 and FY'14-15.

Financial year(s)	FY'11-12	FY'12-13	FY'13-14	FY'14-15
Coking coal imports (MT)	31.80	35.56	36.87	43.71

Table 3: Coking coal import (FY'11-12-FY'14-15). Source: (Ministry of Coal, 2015)

3.3 Near monopoly position of public sector coal mining companies

CIL (Coal India Limited), the largest coal mining company in the world by volume and the predominant coal miner in India (through its operating subsidiaries), along with SCCL (Singareni Collieries Company Limited), contributed ~90 per cent to the total coal production of India (Table 4).

Organisation name	Total production in FY'14-15 (MT)
Coal India Ltd. (CIL)	494.2
Singareni Collieries Company Ltd.	52.5
Other public	20.7
Private (captive) miners	45
Total Production	612.4
Total consumption	608.2

Table 4: Coal Snapshot for India FY'14-15. Consumption is officially marginally lower than production, but additional losses are often booked to the consumer. Sources: (Ministry of Coal, 2014-15); Authors estimates

The private sector mined only ~45 MT of coal in FY'14-15 (captive consumption), and the private miners are not allowed to sell coal commercially, their production is intended for a notified end

⁹ Majority of Indian thermal coal/steam coal imports are from Indonesia. In FY'14-15 India imported 70% (118.215 MT) of steam coal/thermal coal from Indonesia (Ministry of Coal, 2014-15).

use only (which can be regulated: power generation for utilities—or non-regulated: power generation for operating cement/steel/aluminium/any other notified end use based manufacturing unit). The monopoly position of public sector firms makes coal a controlled good—without an independent regulator—limiting private capital and even new technologies. This is despite CIL being a publicly listed company, a step which was initially met with resistance by the miners, but was later enforced resulting in transparency and improvement in much of its operations.

3.4 Ambitious coal production targets for the future?

The Ministry of Coal (Government of India) recently announced a target of 1.5 billion tonnes of coal production by 2020 (IANS, 2015), of which CIL is expected to contribute 1 billion tonnes, while the remainder is expected from the private (captive) miners. Given the very low output from private miners today, ~45 MT of the total indigenous production (7.4 per cent of the total coal production of India in FY'14-15), it appears a herculean, if not unfeasible, task requiring 11 times growth, or a CAGR of ~61 per cent to reach 500 MT by 2020.

On the other hand, CIL (and the other mining PSUs) needs to increase production as well through new capacity or increased production from existing mines. To reach its 1 billion tonne target for 2020, the public sector as an aggregate needs to grow at 12 per cent CAGR, however if the growth target is only for CIL and not the entire public sector then the CIL (only) CAGR stands at 15 per cent. Although CIL did achieve 8.5 per cent growth YoY in FY'15-16, its best ever, it still missed its guidance by 12 MT, settling for 538 MT in the last fiscal (CIL, 2016). Based upon past performance, even the 12 per cent required growth for CIL seems ambitious and possibly unlikely, especially in the future on a larger base. A 12 per cent growth on a 500 base is a lot easier than on an 800 base. Having said that, CIL is the only organisation that has the scale and ability to reach the targeted coal production by 2020.

However, even before one gets to the point of discussing how to reach the target, there are important questions that need to be answered: Are coal production targets for 2020 realistic? Does India actually need to mine as much coal by 2020? Will it be able to absorb all of the additional production? Is there a baseline import requirement that would still be required, even if indigenous coal production increases?

3.5 Research objective and methodology

The objective of this paper is to examine the 1.5 billion tonnes of coal production target, using a mathematical model to arrive at a realistic value of coal requirement in 2020. The step-wise methodology is below:

- Examine all present demand of coal from various sectors and look into possible growth over coming years
- Make data and assumption-driven extrapolations of demand across various sectors
 - Use FY'14-15 as the base financial year unless stated otherwise
 - Power sector dominates consumption, hence is the main focus of the study

- GDP growth rate is nominally pegged at 8 per cent between 2015 and 2020 (study period), sensitivity has been used on top to analyse alternative performance scenarios as well.
- Analyse plant-level data on power plants planned/upcoming
- Apply assumptions based on location (coastal/non-coastal), technology (sub-critical/super-critical) and age of plants
- Utilise data from CEA, other GoI sources, news reports, and paid (subscription) industry analysis

Among the many sectors where coal is used, the majority of coal demand (~77 per cent in FY'14-15) is from thermal power plants for electricity generation, and the remaining sectors contribute only ~23 per cent of coal demand in India. This research uses the actual data for FY'14-15 to arrive at assumption-driven estimates of coal required for expected increase in thermal generation capacity in 2020. For the remaining (~23 per cent in FY'14-15) coal demand, projections based on sectoral growth rates, calculated from historical values of GDP elasticities of the respective sectors, are used to complete the analysis.

For triangulating, similar calculations for coal requirement are made on the demand side, based mainly on detailed projections of expected increase in electricity demand by 2020 keeping the values of non-power coal consumption as is from the supply-side estimates. A comparison between demand and supply side requirements of coal provides an objective assessment of the coal production targets set by the government for 2020.

4 Power sector overview

Since the power sector (electricity) constitutes the bulk of coal demand, we begin with a detailed overview of the current status of the power sector (especially coal-based power sector).

Figure 4 shows the change in total capacity between years 2014 and 2016 by type. Out of the overall 11 per cent capacity increase (between 2015 and 2016), the maximum capacity addition (absolute value terms between 2015 and 2016) was in thermal (coal) power plants (~20 GW) and thereafter in RE (~7 GW). As on 31 March 2015, the share of renewable and nuclear was only 14 per cent by capacity. Coal-based thermal power units made up 61 per cent of the total installed capacity (GW) at the end of FY 2015, but have a much higher share based on generation (kWh), 79 per cent¹⁰.

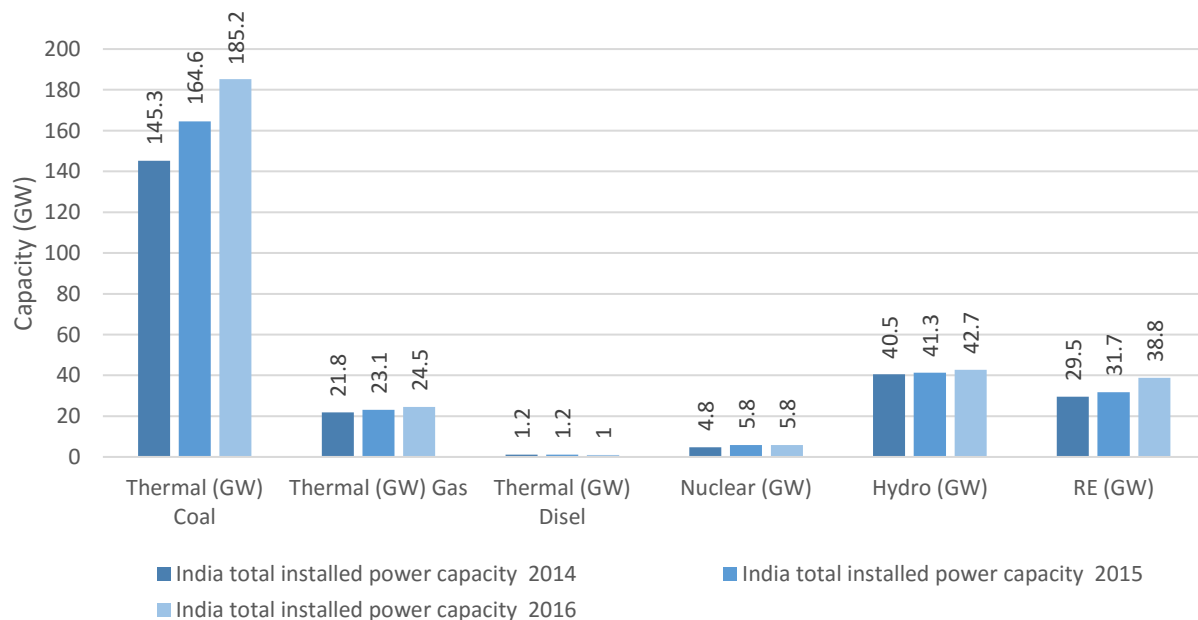


Figure 4: Total installed power capacity in India (2014 – 2016). Sources: (CEA, CEA Monthly Executive Summary Power Sector, April 2014) (CEA, CEA Monthly Executive Summary Power Sector, April, 2015) (CEA, CEA Monthly Executive Summary Power Sector, April, 2016).

¹⁰ While official data (CEA) lists total thermal share as 79 per cent of generation in FY'14-15, Almost 3.7 per cent of this (absolute share) is from gas. For 2020, as a starting point, we assume 79 per cent of BUs from coal for the following reasons: (1) hydropower capacity growth has been limited, and its share of generation is likely to fall (it also varies significantly with the monsoons); (2) Gas share depends heavily on both gas availability/pricing as well as its chosen duty city (baseload vs. peaking). If it runs as a peaker, more capacity can be utilized, but with low PLFs; (3) this is a conservative number from a coal requirement number - any growth of other thermal (or hydro) would decrease the coal requirement.

4.1 Coal dominates electricity generated (79 per cent in FY'14-15)

As Figure 5 shows, coal dominates generation¹¹, whereas the share of generation is low for hydro and even lower for Renewable Energy (RE). For the former, India is reliant on limited (seasonal) rains, but RE has an inherent limitation in its ability to generate, and expected Plant Load Factors (PLFs), also termed Capacity Utilisation Factors (CUFs), are only in the range of 20 per cent.

There are ambitious plans to install 175 GW of renewable capacity in India by 2022 (PTI, 2015) but the growth rate required to reach this target by 2022 (at a steady rate of increase) is 27 per cent CAGR while the past years (FY'15-16) growth in RE capacity has been around 22 per cent, a jump over the previous year's 8 per cent (FY'14-15). High growth rates may be easier on a relatively low existing base of installed RE capacity in the country but the challenge is in replicating if not enhancing this growth rate over multiple years.

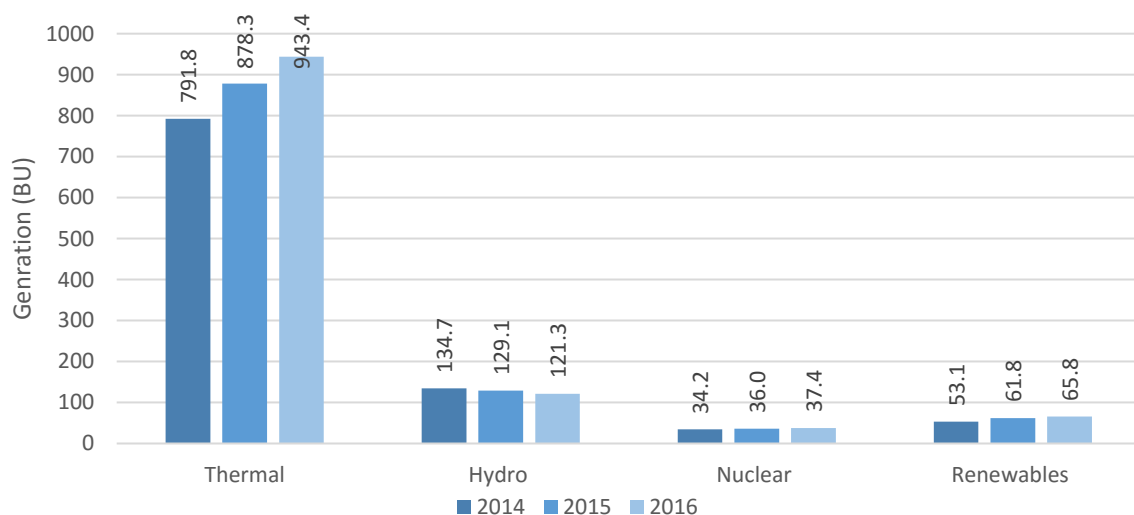


Figure 5: FY'14-15 Electricity generation (BU) by sector. Note: There is no breakup shown for different thermal sources; but coal dominates and its share may be higher given the low use of (expensive) gas. Source: CEA data

4.2 Lagging in technology use

As shown earlier, India had ~165 GW of installed capacity of coal based thermal power plants (FY'14-15) of which only around 16.3 per cent (26.8 GW) are based on super-critical technology, rest being sub-critical (138.2 GW). There are no ultra-supercritical technology based thermal power plants at the moment and none are expected till 2022 (India Energy Government, 2014). These technologies improve the plant efficiency reducing coal requirements, also reducing environmental impacts, both in terms of pollution and water requirements. The high quantum of sub-critical thermal power plants (~84 per cent) could partly be due to a legacy of public sector led

¹¹ CEA combines coal with other fossil fuels as thermal in most publications, but the total is mostly coal; gas use by share has not risen as planned due to costs/availability

development and its lack of capital and innovation. The government has recently come up with a mandate (Press Bureau, 2015) to add only super-critical thermal generation capacity subsequent to 2017. With increased participation of the private sector and an increased focus on environmental damage, the future for efficient boiler technologies looks promising, but India is not at the forefront of plant technologies.

4.3 Low efficiency values for existing plants

Indian power plants lag in average operational efficiency values. The global efficiency values for coal based thermal plants vary widely between 30 and 45 per cent (IEA, 2012), domestic plants have managed to achieve a maximum of 33 per cent for sub-critical and 38 per cent for super-critical (Chandra Bhushan, 2015), respectively, with the lowest efficiency values for sub-critical power plants at ~29 per cent. A detailed 2008 study of a sample of sub-critical power plants (85) indicated an average operational efficiency values of ~31 per cent (IGEN, 2008). To be fair, there are technical limits to achieving higher operational efficiency values in India due to differences in climactic conditions from global comparisons.

While efficiency is foremost limited by plant technologies (largely via operating temperatures and pressure), there are other factors that are relevant for India, including operating duty cycle and whether the plants operate at ~full load or not. Any plant operating at part load loses efficiency, and this gets far worse with cycling, loading up and down (also increases the wear and tear). While it is beyond the scope of this paper to examine such issues in detail (especially grid operator load despatch), these are known to exist and demand greater analysis.

4.4 Future coal-based power capacity: A lot more of the same?

With a lot of new proposed thermal power plants (200+) (India Inframonitor, 2015-16) in various stages of development and completion, there seems to be massive growth on the anvil for thermal power capacity by 2020. Table 5 shows the projects and the capacity in the pipeline by 2020. Even though the number of proposed future power projects is large (a total of 268 projects translating into 325 GW), about 147 GW of the total has projected commissioning dates before 2020, as shown below.

	Project count	Capacity total (GW)	Projected capacity (GW) by 2020
Announced (no construction reported as of September 2015)	200	255.8	77.8
Under construction (as of September 2015)	68	69.2	69.2
Grand total	268	325.0	147

Table 5: Summary table of upcoming projects by 2020. Source: (India Inframonitor, 2015-16)

However, on a closer look, many of the proposed projects are yet to achieve financial closure or the necessary environmental and land clearances to apply for funding. Removing all such plants from the lot throws up ~147 GW of thermal capacity expected to come up by 2020 (at various stages of construction and/or advanced stages in the approval process), doubling the FY'14-15 thermal capacity by 2020. In Section 6.3, we examine growth of new power plants in much more detail.

Future plants are not the same as existing plants. The overwhelming majority will be super-critical, which means they will be more efficient. They are also not randomly distributed, and their location determines their preferred if not optimal source of coal i.e.; not only imported versus domestic, but also the grade of coal, transportation requirements, etc. New capacity also impacts existing capacity in the sense that a finite demand (total coal sector PLF) need not be distributed equally across plants by vintage or location, ownership, etc.

Taking into account historical project slippage rates, all of the capacities in Table 5 are unlikely to make it online by 2020. Even then, the residual capacity coming online could potentially have a material impact on the existing plant PLFs, unless older and inefficient plants are retired.

5 Sectoral coal consumption (power and non-power, FY'14-15)

Coal supply to the power sector is only one facet of coal use. It is also used in other industrial sectors, like aluminium (captive consumption for power generation), cement, steel making (coking coal) and fertilisers. In Section 6 we explain broad assumptions on current (FY'14-15) data underlying future coal demand calculations for power sector and non-power sector.

	Sectors	Demand	Supply		
Coking coal			Domestic	Imports	Total
	Steel and allied sector	17.0	22.3		22.3
	Imports	38.4		43.7	43.7
	Sub Total	55.46	22.3	43.7	66.0
Non coking coal	Sectors	Demand	Supply		
			Domestic	Imports	Total
	Power (Utilities)	551.6	418.5	125 ¹²	543.5
	Power (Captive)	50.0	53.5	26 ¹³	79.6
	Sponge Iron	23.9	14.7	9.2 ¹⁴	23.9
	Cement	26.1	11.4	8.1 ¹⁵	19.5
	Others	80.0	87.9	0 ¹⁶	87.9
	Sub Total	731.6	585.9	168.4	754.3
	Total	787.0	608.2	212.1	820.3

Table 6: Coal used in various industries in 2015. Source: (Ministry of Coal, 2014-15), (CEA, CEA Monthly Executive Summary Power Sector, April, 2015) and Authors' analysis

Table 6 is a modification of the demand-supply as reported in the provisional coal statistics from the MoC (Coal Controller Organization, 2016). Demand is a prospective estimate at the beginning of a year, however, actual supply through the year can vary based upon multiple factors. Hence, the *demand* side numbers are used *as is* as per official reporting by agencies (Ministry of Coal, 2014-15) while the *supply* side numbers are a mix of reported numbers and independent estimates based upon inputs from various sources. Data usage protocol, and *supply* side estimation methodology from various sources in is explained in Section 14 (Appendix A).

¹² Expected value of imports for power utilities based upon expert consultations.

¹³ Expected value of imports for Captive power plants based upon expert consultations.

¹⁴ Imports attributed to sponge iron based upon demand from the sector.

¹⁵ Imports attributed to the cement sector considering availability of alternate material and also requirement of imports.

¹⁶ Assumed to be zero in the face of excess supply from domestic sources, though there are reports of some coal imports by brick industry today.

6 Sectoral assumptions for future coal demand calculations

It is not possible to wish away coal imports completely due to India's deficit coking coal reserves, and the need for blending in power plants. The coal computation of future coal requirements through both the capacity side and the demand side hinges on the power sector, owing to its large share of total coal demand. The current supply of coal across (FY'14-15) sectors is given in Table 7.

Coal type	Coking coal (MT)			Non coking coal (MT)			Total coal (MT)	
Source	Domestic	Imports	Total	Domestic	Imports	Total	Domestic (a)	Imports (b)
Steel (+boilers)	22.3	43.7	66	0.4		0.4	22.7	43.7
Sponge iron				14.7	9.2	23.9	14.7	9.2
Cement				11.4	8.1	19.5	11.4	8.1
Fertiliser				2.3		2.3	2.3	
Others				85.6		85.6	85.6	
Power-utility				418.5	125	544	418.5	125
Power-captive				53.5	26	80	53.5	26
Assessment year (FY'14-15)	22.3	43.7	66	586.4	168.4	754.8	608.7	212.1
Total							(a+b) = 820.8	

Table 7: Coal supply to sectors (official through FY'14-15). Source: (Ministry of Coal, 2014-15)

Based upon empirical data, the following assumptions were used for projecting coal demand in 2020.

6.1 Power sector assumptions

Power sector assumptions change if one is approaching the analysis from either the bottom up electricity demand projections or capacity of upcoming thermal power plants. The assumptions below are used for thermal power plant capacity side calculations¹⁷ only.

6.1.1 PLF

PLF of 64.46 per cent (Central Electricity Authority, 2015) is used as a base case for all calculations throughout this research. However, it is worthwhile to note that the value (of PLF) would be impacted by several factors, including but not limited to, the addition of new capacity to the existing base during the research period (which is ~21 GW). The actual production, limited by demand, may not pick up in the same measure, depressing the overall PLF. Also, the PLF is more of an aggregate value over the entire year, hence, is not an accurate representation of the actual PLF values at any given point in time. The variation in power demand over daily or seasonal cycles would probably throw up a different value of PLF since the power generation is not the same every day and aggregation of PLF masks such granularity.

¹⁷ Capacity side calculations imply future coal projections where outlook for coal consumption in the power sector is based upon thermal power plant capacity expected online by 2020.

6.1.2 Efficiency

6.1.2.1 Sub-critical power plants (FY'14-15)

For realistic assumptions of efficiency in thermal power plants, a public report from the CEA website on the "Mapping of 85 pulverized coal fired thermal power generating units in different states (Under Indo-German Energy Program-IGEN)" was analysed. The report (IGEN, 2008) studied the operating parameters for 85 power plants of various age and capacities with data on various design and operating parameters for each of these units. While the report is slightly dated, it covers historical plants in detail, thus providing a good baseline for existing plants.

For the purpose of this study, raw data on three key parameters; age of the plant, design efficiency, operating efficiency, and percentage deviation from design parameters for 74 of these plants was used. The remaining plants (11) were removed from the analysis as they were found to be outliers in their segment. Table 9, lists the sample plants on operating and design efficiency with weighted averages of all parameters in the last row.

Regression Statistics		
R-squared	0.814	
Adjusted R-squared	0.752	
Standard Error of Regression	0.009	
# Cases	9	
<i>Coefficient estimates</i>		P-values
Constant	0.318	(0.000)
Average age	-0.001	(0.026)
Capacity	0	(0.080)

Table 8: Regression statistics for regression between operating efficiency (dependent variable) and average age and plant type (independent variables).

A simple regression, results shown in Table 8, on operating efficiency (dependent variable) based upon independent variables; average age and plant type (capacity in MW) gives an R-squared value of 0.814 and is negatively correlated with average age and positively correlated with plant capacity. However, the P values for both are statistically insignificant, 0.026 for average age (coefficient, -0.001) and 0.08 for capacity (coefficient, 0), only the constant with a coefficient 0.318 with p value of 0.000 is statistically significant. Based upon results of the regression, the null hypothesis that age and plant type have no impact on the efficiency of a plant is accepted. Average age, however, is a better influencer compared to the plant capacity.

Plant type (MW)	Total Number Plants	Average age	Design Efficiency (a)	Operating Efficiency (b)	Percentage difference ((b)/(a))%
500 MW	5	14	38.07%	33.51%	88.02%
250 MW	4	8	37.32%	31.98%	85.70%
210 MW(2000+)	3	2	37.22%	33.66%	85.86%
210 MW (1990-1999)	18	14	36.73%	32.48%	88.41%
210 MW (till 1989)	27	24	36.15%	31.04%	90.43%
140 MW	3	38	35.92%	30.74%	83.90%
120-125 MW	7	29	35.52%	29.33%	85.60%
100-110 MW (age 20s)	3	24	36.67%	30.12%	82.59%
100-110 MW (age 30+)	4	33	35.04%	28.72%	81.98%
Weighted Averages	(74/85)	20.66	36.42%	31.16%	

Table 9: Analysis on operating and design efficiencies estimated for 74 of the 85 power plants covered in the report by IGEN. This removes 11 outliers for the above calculations. SOURCE: (IGEN, 2008)

Based on the analysis in Table 9, an average value of 31.16 per cent for operating efficiency of sub-critical plants was used for further calculations.

6.1.2.2 Future sub-critical power plants (expected by 2020)

A more efficient scenario with a higher efficiency for the upcoming sub-critical power plants was considered, separating the current efficiencies and future values to account for increase in system efficiency by a combination of retiring older plants and better efficiencies in general for the newer plants. An efficiency value of 34 per cent was considered, this is a conservative value and a sensitivity on top of this has been built into the model (explained later in this report).

6.1.2.3 Super-critical power plants (FY'14-15)

In the absence of any report on the actual operating efficiencies of super-critical power plants, the CSE report titled "Heat on Power - Green rating of coal-based thermal power plants" was used (Chandra Bhushan, 2015) with a value of 38 per cent efficiency for super-critical plants.

6.1.2.4 Future super-critical power plants (expected by 2020)

Similar to the assignment of sub-critical power plants, a different value for efficiency of upcoming super-critical power plants was considered, separating the current and future values to account for overall efficiency gains in the system with newer capacities and better operational discipline. A marginal increase in efficiency value by 0.5 per cent to reach a total of 38.5 per cent over current super-critical plants was considered. This is a conservative value and a sensitivity on top of this has been built into the model—elaborated subsequently.

6.1.2.5 Average grade of coal and specific coal consumption

The specific coal consumption in India (kilograms of coal required per kWh generation) varies widely by factors including technology, size, vintage, and operations (loading compared to nominal capacity). The recent CSE report titled “Heat on Power - Green rating of coal-based thermal power plants” (Chandra Bhushan, 2015) used a sample of 47 power plants—a representative mix of private and the public sector (central/state) units, covering half of the total capacity in 16 states—to study coal power’s efficiency and environmental impact. The report cited variations in the specific coal consumption for plants based upon coal type (imported coal based power plants reporting lower specific coal consumption), use of complementary fuel (like corex gas, a by-product of steel making) etc. however, the average specific coal consumption across the country was reported to be in the range of 0.71 Kg/Kwh (for FY’12-13, page 32 of the report).

For this research, specific coal consumption was calculated by segregating imports and domestic coal in FY’14-15. Only utility grade electricity was considered for calculations, leaving aside the captive capacities. Boundary conditions were set based upon known values of coal consumption in power sector;

- 418.5 MT of domestic coal and 125 MT of imported coal,
- technology split of generating capacities—137.8 GW sub-critical and 26.8 GW super-critical,
- average efficiency values of sub-critical and super-critical power plants—31 per cent for sub-critical and 38 per cent for super-critical and,
- plant PLFs on annual average basis – 64.46 per cent

The boundary conditions helped iterate assumptions of average GCV values of respective coal types to find the optimal value of specific coal consumption.

Based on the above assumptions the specific coal consumption value was calculated, shown in Table 10.

	Sub-critical			Super-critical		
	Specific coal consumption	GCV	Coal grade (India equivalent)	Specific coal consumption	GCV	Coal grade (India equivalent)
	Kg/Kwh	Kcal/KG	Rating	Kg/Kwh	Kcal/KG	Rating
Imported coal	0.505	5,500		0.412	5,500	
Domestic coal	0.642	4,325.3	G11 (Upper Bound, 4,300)	0.523	4,325.3	G11 (Upper Bound, 4,300)

Table 10: GCV calculations for sub-critical and super-critical coals.

The calculated values of specific coal consumption and grade of coal (G1-G17) were applied to the model for use in future demand/capacity based coal calculations. A comparison of the GCV values for imported and domestic coal throws up a comparative ratio. The ratio (1:1.27) supplies the

quantum increase in domestic coal required (in tonnes) for each tonne of imported coal being removed from the system, to keep the heat value of coal in the system constant.

It is also important to note the following in the context of the above calculations:

- The values of imported coal consumed in the power sector in FY'14-15 is an assumption, in the absence of exact data available
- The value of efficiency also impacts coal grade on an aggregate basis and this is also an assumption, although based on a 2008 report (IGEN, 2008) for sub-critical power plants the value for super-critical power plants is also based upon a CSE report (Chandra Bhushan, 2015)
- The GCV values though calculated, the actual value used (G11) for future calculations are a bit different. Reasons include sub and cross-category splits in usage of coal, accounting for losses in the system (coal transport), disputes in coal grades delivered, etc.

6.1.3 Coal leakage

Leakage is defined as the coal lost in transit and pilferage, based on the material difference between the demand and supply of coal reported in FY'14-15 (Ministry of Coal, 2014-15) and expert views on the amount of coal lost to theft/spillage/fire, during storage, transportation, and loading-unloading. A 4 per cent value to the leakage of coal was applied in the model (comparing mining to consumption by users).

6.2 Non-power sector assumptions

The assumptions for the non-power sector remain the same for both power plant capacity and power demand based coal projections.

For the non-power sector, a GDP elasticity was applied for calculating the future growth rate of the sector with corresponding growth in GDP (assumed 8 per cent for this model as a base using historic data). Table 11 shows sectoral elasticity values used for projecting future coal demand of the major non-power sectors:

Non-power usage (2015)	GDP growth rate	Elasticity	Sectoral growth rates
Steel (+ Boiler)	8%	1.1	8.8%
Sponge iron	8%	1.1	8.8%
Power (captive)	8%	0.9	7.2%
Cement	8%	NA	11.8% ¹⁸
Fertiliser	8%	0.78	6.2%
Others	8%	1	8.0%

Table 11: GDP elasticities for specific sectors used for calculation. Data sources are given in following section.

¹⁸ GDP elasticity values of cement sector is not available however, a future growth rate for cement is defined in one of the sources used.

6.2.1 Steel (+ boiler)

Steel is one of the major infrastructure sectors that is expected to grow with increased demand for goods and construction. The historical GDP elasticity of 1.1 according to sources (Steel, 2016) lays the groundwork for a higher GDP growth rate through 2020.

6.2.2 Captive Power

CEA monthly reports do not cover captive power plants in great detail except for capacity details. Captive power is generated by a power plant for a fixed End Use (EU), and does not feed into the grid. Notable large-scale users include industries like aluminium, steel etc. The *historical* growth rate for the overall power sector *had* a GDP elasticity greater than 1 (Planning Commission, 2014) however, the GDP elasticity of electricity reduced from 1.3 to 1.06 between 1981 and 2001, and recent data (albeit with a shorter time horizon) show even lower elasticities. It is further expected to decline as GDP grows, therefore, to ensure a conservative estimate it is assumed at 0.9 for the future. Section 9.1.1 on power demand goes into more detail.

6.2.3 Cement

The cement industry in India is set to grow with the increase in the need for urban housing. However, the cement industry can and does use alternative fuels as opposed to many industries that do not have such flexibility. These choices are based on a combination of pricing, availability of alternatives, and plant designs. In case of any availability or price concerns related to coal, it can shift to alternative sources of fuel. A forecasted growth rate of 11.58 per cent (India Cement Review, 2016), has been used for this sector in the absence of GDP elasticity data.

6.2.4 Fertiliser

The fertiliser sector, though comparatively not a major consumer of coal, sits at an impactful position in the economy. However, the use of coal for this sector is slated to fall below expected GDP growth rates (IGIDR, 2016) hence, a less than 1 base value for GDP elasticity has been used.

6.2.5 Other users of coal

The official segment titled “Others” includes a number of applications that have been clubbed together including brick kiln works, basic metal works etc. While, after the new coal distribution policy in 2007 (MoC, 2016), the distribution of coal to non-bulk consumers has been liberalised (for those that have a demand 4,200 Metric Tonnes or less per annum the state government arranges coal through CIL), some imports in this sector cannot be ruled out. For the purpose of this study, however, no imports were attributed to this segment (which may not necessarily hold as there are reports of brick kiln industry importing high sulphur American coal). To account for multiple sectors and industries a uniform peg with GDP growth rate at 1:1 has been considered for the base case.

6.3 Calculating power capacity expected online till 2020

As discussed in Section 4.4, the anticipated future capacities are large. However, adding a layer to the analysis, in addition to the cut off for projects expected to come up by 2020, there is a firming

up of capacities by binning in buckets based upon their progress on the construction/approval process. Upcoming capacities were binned (147 GW) on the basis of their status on three key variables and one additional exogenous variable (explained later) impacting the project approval and commissioning. Weights have been assigned to the three key factors¹⁹ (Table 12):

- Current status of land acquisition
- Current status of environmental clearance
- Current status of financial closure

With a 0/1 for each of the above based upon status: in-progress/achieved, respectively.

Environmental clearance is *de facto* first among equals. It is necessary for closing land acquisition and securing funding and has, therefore, been assigned the highest possible weightage (35 per cent) among the three key impact variables. A step down of 5 per cent for the second highest weighted variable: land acquisition (weightage of 30 per cent), and another 5 per cent step down for the variable financial closure (weightage of 25 per cent), together summing up to 90 per cent. The rank ordering of the impact variables represents the potential impact that they have on the successful execution of a thermal power project. The residual (10 per cent) has been attributed to an exogenous positive variable (0/1 defined as the sum of all residual events, without overt individual probabilities, that can impact the project commissioning), absence of which (0) implies that the project will not go through even after securing clearance on all three key variables. An example of plausible events that could stall the project could be local protests by villagers against land compensation, etc.

To ensure a conservative estimate of future power plant projections, the exogenous variable²⁰ has been assumed "0" for all categories, except the category 0-0-0, it is expected that some of these, in spite of being far away from project closure, may still might manage to go through at a later stage. This does not imply that projects without clearances can get through, though a positive prospect for these projects has been considered to assign probabilities in the aforementioned fashion.

¹⁹ Those plants that are under construction (after having secured all clearances) have a higher probability of coming up in future as opposed to those that are yet to commence construction (also have secured all the clearances). Since both of these categories have been clubbed together for assigning probabilities, it is important to note that a higher probability should be assigned to those under construction and lower value to those without. However, this aspect is reflected in the sensitivity (as opposed to the base case) later on in the report.

²⁰ Authors have assigned a low but finite probability under the new exogenous variable not because of randomness per se but also because there might be plants which have some clearances (and/or political support) but aren't capture in the database(s). CEA itself found additional capacity coming online the current Plan (2012-17) due to things slipping below its radar.

Methodology	Weightage	Respective clearance status (2015)									2020
Environmental clearance	35%	1	1	1	1	1	0	0	0	0	Overall
Land acquisition	30%	1	1	1	0	0	1	1	0	0	
Financial closure	25%	1	1	0	1	0	1	0	1	0	
Exogenous support variable	10%	1	0	0	0	0	0	0	0	1	
1-Slippage %	100%	100%	90%	65%	60%	35%	55%	30%	25%	10%	75%
Slippage % ²¹		0%	10%	35%	40%	65%	45%	70%	75%	90%	25%
Projected maximum capacity addition by type [GW]		-	89.9	14.0	20.3	4.6	7.2	4.9	1.4	4.7	146.9
Private		-	57.5	5.3	11.8	4.6	5.9	4.9 ²²	1.4	3.1	94.4
Public		-	32.4	8.7	8.5		1.3			1.6	52.5
Possible online (After slippage)		-	80.9	9.1	12.2	1.6	4.0	1.5	0.4	0.5	110.0

Table 12: Methodology for filtering various projects on the status of completion of their respective approvals.

Those plants that have all three approvals in place (1,1,1) are weighted at the highest probability (and thus lowest “slippage”) of getting commissioned, while those that have none have the lowest probability of coming online (0,0,0), others being in between (0,1,0 or 1,0,0 or 0,0,1).

After ranking the prospective capacities upon the binary probabilities of the three causative variables, duly weighted, a slippage rate was found (Table 12) by summing up the weights of the respective variable status (0/1) and an order for binning thus defined. A differential slippage rate (between minimum 10 per cent to maximum 90 per cent, for plants that have maximum clearances and plants with minimum clearances respectively) was applied to weigh the projected power capacity expected online by 2020. With the applied assumptions on slippage rates, the computed average slippage rate for the entire 147 GW was 25 per cent²³ giving a most likely value of 110²⁴ (+5) GW of power capacity expected online till 2020.

²¹ Slippage rate, is defined as the percentage of total projects that are expected to fall behind schedule and not come up in the time span planned for their execution. These projects may come up later but for the analysis timeframe such capacities are discounted from calculation.

²³ The calculated slippage rate is an approximation and is close to actual slippage rate for last five years – reported on the basis of CEA data and expert interviews with subject matter experts.

²⁴ An additional 5 GW of capacity has been added to the total (sub-critical) to account for new projects online between the beginning of the research period and the research closing date. The total capacity thus becomes 115 GW by 2020.

While one may question how a plant can come on stream in five years if it lacks one or more of three key clearances, it would be good to note that these data points are based on clearances prior to 2015 in many cases. Some of the (partial) clearances came even earlier, and there is a likelihood that those already obtained, or are close to being obtained, haven't reflected into public and private databases, till the point where data is assessed for this report.

6.4 Future coal imports (calculated)

Assumptions for future imports of coal for the power sector are based upon multiple factors elaborated in the section below. Future imports for non-power sectors are considered to grow proportionately to maintain the current ratio between indigenous coal and imports.

Computation methodology for power sector imports is explained below.

6.4.1 Power plants segmentation methodology

At the first level of analysis power capacities were listed and then classified into two parts:

- Current capacity FY'14-15 (164.6 GW)
- Additional future capacity by 2020 (115²⁵ GW)

The capacities (present and upcoming) were then arranged in a matrix based upon the following key criterion:

- Location (coastal states/non-coastal states),
- Technology (sub-critical/super-critical) and,
- Coal usage (running on imported coal or domestic coal).

The above classifications are not mutually exclusive, implying a non-coastal power plant may be either sub-critical or super-critical and may/may not be using blended coal for fuel. The segmentation applies a layered approach to calibrating the probability of future coal imports as newer power plants are commissioned and also pegs a number to the plausible imports for the existing power plants in future (2020). On the basis of these criteria and assumptions explained below, the source of coal for different plants was estimated.

6.4.2 Procedure for segmentation

6.4.2.1 *Present capacities*

All the present capacities, plant level, were individually marked on the basis of their spatial location (latitude/longitude), capacities (GW), technology used (sub-critical/super-critical) and distance (KM) from the nearest port.²⁶ Among the present capacities those in states that have a coastline (Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Odisha, Tamil Nadu, and West Bengal) were

²⁵ The calculation methodology for expected capacity is explained in Section 6.3, however to reiterate the 5GW additional capacity is attributable to the capacity already commissioned between 31 March 2015 and 30 September 2015, the research period for this study.

²⁶As the crow flies/actual distance through marked roads, based on available information on google maps and various other online sources

identified and listed separately. After listing, capacities were binned into categories on the basis of their distance from the nearest port, and technology used, as shown in Table 13.

	Sub-critical (GW)				Super-critical (GW)			
Distances (for coastal states)	<40 km	40-100 km	100-500 km	>500 km	<40 km	40-100 km	100-500 km	>500 km
Andhra Pradesh	2.90	0.52	3.31				2.26	
Gujarat	1.20	0.50	4.59		7.30			
Karnataka	1.20		3.080					
Maharashtra	1.40	²⁷	1.92	11.47				3.96
Odisha			11.48					
Tamil Nadu	6.13	3.24	0.84					
West Bengal		2.01	11.25					
Total	12.83	6.27	36.48	11.47	7.30	0	2.26	3.96

Table 13: Binning of present capacities, in coastal states on the basis of technology and distances from the nearest port.

Based upon Table 13, a 2x2 classification of existing power capacities is calculated (Table 14).

	Sub-critical (GW)	Super-critical (GW)	Total (GW)
Coastal	67.05	13.52	80.57
Non-coastal	70.72	13.30	84.02
Total	137.77	26.82	164.59

Table 14: 2x2 classification of existing power plants on technology and spatial locations.

6.4.2.2 Upcoming power plant capacities

A similar procedure was followed for future/upcoming capacities as well (applying uniform slippage rate²⁸ of 25 per cent after binning in categories), where information on four key parameters – spatial location, capacities, technology used, and distance from the nearest port²⁹ – were recorded. Some port development was co-terminus with the commissioning of the power plants, to operate dedicated coal import terminals at the ports. In such cases, instead of the operational port in the neighbourhood the dedicated upcoming port was considered, to take into account the future distances from port to the power plant for the upcoming plants. A snapshot of the future capacities in coastal states, binned on the basis of their distance from closest ports, is given in Table 15.

²⁷ Blanks imply no capacity in the particular category

²⁸ Slippage rate, is defined as the percentage of total projects that are expected to fall behind schedule and not come up in the time span planned for their execution. These projects may come up later but for the analysis timeframe such capacities are discounted from calculation.

²⁹ In a mild departure from the calibration type in existing capacities, there were some capacities planned for the future that had a dedicated port terminal as well, for e.g.: the Government of Andhra Pradesh (GoAP) has permitted construction of a dedicated captive jetty at Meghavaram, 10 km south of Bhavanapadu port, for import of coal (India Inframonitor, 2015-16)

	Sub-critical (GW)				Super-critical (GW)			
Distances (for coastal states)	<40 km	40-100 km	100-500 km	>500 km	<40 km	40-100 km	100-500 km	>500 km
Andhra Pradesh	2.99		1.70		7.54	1.6	0.80	
Gujarat	1.96	0.03	0.10		2.78			
Karnataka	1.20		0.50				0.70	4.00
Maharashtra	0.05	0.39	3.31	4.65	2.52		1.32	3.30
Odisha	0.06		4.69		5.89	1.32	3.96	
Tamil Nadu	4.72	2.92				0.60		
West Bengal	0.60	0.45	1.63				1.82	
Total	11.59	3.79	11.93	4.65	18.73	3.52	8.60	7.30

Table 15: Binning of future capacities, in coastal states on the basis of technology and distances from coast.

Applying 25 per cent uniform slippage rate on top to the above, we get the capacities as given in Table 16.

	Sub-critical (GW)				Super-critical (GW)			
Distances (for coastal states)	<40 km	40-100 km	100-500 km	>500 km	<40 km	40-100 km	100-500 km	>500 km
Andhra Pradesh	2.24		1.28		5.66	1.20	0.60	
Gujarat	1.47	0.02	0.07		2.08			
Karnataka	0.90		0.37				0.53	3.00
Maharashtra	0.04	0.29	2.48	3.49	1.89		0.99	2.47
Odisha	0.05		3.51		4.42	0.99	2.97	
Tamil Nadu	3.54	2.19				0.45		
West Bengal	0.45	0.34	1.22				1.37	
Total	8.69	2.84	8.95	3.49	14.05	2.64	6.45	5.47

Table 16: Binned future capacities post slippage, in coastal states, on the basis of technology and distances from coast.

A 2x2 categorisation of upcoming capacities (post slippage) is provided in Table 17.

	Sub-critical (GW)	Super-critical (GW)	Total (GW)
Coastal	23.97	28.61	52.59
Non-coastal	21.29	36.32	57.62
Total	45.27	64.94	110.20

Table 17: 2x2 classification of expected (future) power plants on technology and spatial locations.

6.4.3 Assessing probabilities of future imports

Power plants are spread all over the country, some are inland, others at the pit head, and some at the coast. In terms of coal requirement, the inland plants would need coal transportation from various sources; mainly domestic coal guaranteed by long term linkages through Fuel Supply Agreements (FSAs) with domestic miners (typically CIL/SCCL), and also some imports based on blending requirements. In its coal import notification FY'15-16 (CEA, 2015) it is evident many inland

plants blend imported coal to their feed. Blending with imported coal could be required by a power plant due to multiple reasons:

- Technology restrictions: boiler technology used by a power plant could be built for a specific feed type mandating imports for matching the required fuel characteristics,
- Economic reasons: imported coal could be cheaper on a per unit energy basis,
- Environmental reasons: blending of low ash imported coal (till recently only coal with ash content of 12 per cent and less was allowed for imports (PTI, 2015)), reducing environmental pollution load from usage of high ash domestic coal.

Pit head power plants are typically built to use coal available at the mine itself as it saves transportation costs. However, depending on the variance in the quality of mined coal over the life of mine there may still be some import requirements in the future.

Coastal power plants,³⁰ are at the other end of the spectrum. By virtue of being on the coast/near the coast, the plants are most likely to be designed to run on imported coal. The caveat being, even in a coastal state those power plants far from the coast (>500 km) may benefit from their proximity to a mine (if at all) and may like to blend, if not entirely run on domestic coal. The examples of entirely imported coal dependent plants are: Mundra Thermal Power Plant (Adani) and Mundra UMPP (Tata).

6.4.3.1 Procedure for allotting probabilities (imports for coastal power plants)

The import probabilities in Table 19 are based on the scenario where maximum (import) probability is assigned to power plants closest to the ports. Thereafter, within a technology type (sub-critical/super-critical) probability of import is expected to decrease with an increase in distance from the port. A step value of 25 per cent has been assigned in reducing probabilities from left to right within a technology type. Among the states (vertically) the probability of imports decreases with proximity to coal bearing regions (availability of indigenous coal) hence the lower assigned probabilities for Odisha and West Bengal. Based upon above, AP should also get a lower rating for plants within 40 km however, with the reorganisation of the state, Telangana now has the mineral bearing areas of the state, whereas the distance of Khammam (the border of AP and Telangana and also a coal bearing district of Telangana) from port is ~200 km hence, the higher probability of imports for AP.

6.4.3.2 Incorporating port capacity and distances

The top 20 ports that handle almost 94 per cent of the total coal imports in the country are given in Table 18.

³⁰ The analysis starts by taking into account all the states with a coastline. The upcoming capacities in these states are then binned in categories based upon the distance from the port. Based upon distance from the (nearest) port the power plant may actually be far inland as opposed to being close to the port. Such nuances have been incorporated in the analysis.

S. no.	Ports	Percentage share (of non-coking coal imports)
1	Mundra	14%
2	Dehej	8%
3	Sez Mundra	7%
4	Krishnapatnam	6%
5	Paradeep	6%
6	Visakhapatnam	6%
7	Kandla	5%
8	Gangavaram	5%
9	New Mangalore	4%
10	Dhamra (chandbali)	4%
11	Navlakhi	4%
12	Ennore	4%
13	Chennai	4%
14	Mumbai	3%
15	Tuticorin	3%
16	Bedi	3%
17	Kakinada	3%
18	Magdalla Port	2%
19	Kolkata	2%
20	Marmagoa	2%

Table 18: Ports handling bulk of non-coking coal imports. Source: (Ministry of Coal, 2014-15)

While weighing in probabilities for imports for a coastal state based plant(s) due weightage has been given to the port falling within the state boundaries. In case of a high traffic port (with respect to annual coal imports, as shown in Table 18) falling within the state boundaries, the probability of imports for plants is higher compared to those states with low traffic ports; e.g., Odisha, with higher coal-handling capabilities (Paradeep and Dhamra), has a higher probability of imports even for plants located longer distances from port, compared to West Bengal which has a lower probability of imports at longer distances from the port, since it has less coal-handling-capacities at its ports.

Probability of import	Sub-critical (probabilities)				Super-critical (probabilities)			
Distances (for coastal states)	<40 Km	40-100 km	100-500 km	>500 km	<40 Km	40-100 km	100-500 km	>500 km
Andhra Pradesh	1	1	0.50	0	1	1	0.75	0
Gujarat	1	1	0.75	0	1	1	1	0
Karnataka	1	0	0.50	0	1	0	0.75	0
Maharashtra	1	0.50	0.50	0	1	0.75	0.75	0.25
Odisha	0.75	0.50	0.25	0	0.75	0.50	0.25	0.25
Tamil Nadu	1	1	0.75	0	1	1	0.75	0
West Bengal	0.75	0.25	0	0	0.75	0.25	0.25	0

Table 19: Assigned probabilities to coastal capacities for coal imports. This is based on distance from coast, technology, distance from an inland mineral rich state, and coal handling capacity at the nearest ports.

Super-critical plants are also more efficient and need higher quality coal, thus in the case of super-critical power plants above, the gradient of decrease in probability is smaller with increase in

distances from the ports (left to right). While we do not claim these exact block numbers will mirror reality, these are indicative and some errors would even out, especially, given that these are plant-level characterisations. Operations (PLF) are also important for calculating the coal requirements, which will vary by plant.

6.4.3.3 Calculating future capacities on imported coal

Upon multiplication of binned present capacities (Table 13) with binned probability distribution of imports (Table 19); and binned future capacities (Table 16) with binned probability of imports (Table 19) we get the capacity of *existing* plants expected to run on domestic versus imported coal in the future (2020) (Table 20) and the capacity of *upcoming* plants expected to run on domestic versus imported coal for a base calculation (Table 21).

	Capacity on domestic coal (GW)		Capacity on imported coal (GW)		Total (GW)
	Sub-critical	Super-critical	Sub-critical	Super-critical	
Coastal	38.4	3.5	28.7	10.0	80.6
Non-coastal	70.7	13.3	0.0	0.0	84.0
Grand total	109.1	16.8	28.7	10.0	164.6

Table 20: Current coal power plant capacities expected to import coal in 2020.

	Capacity on domestic coal (GW)		Capacity on imported coal (GW)		Total GW)
	Sub-critical	Super-critical	Sub-critical	Super-critical	
Coastal	10.0	10.2	14.0	18.4	52.6
Non-coastal	21.3	36.3	0.0	0.0	57.6
Grand total	31.3	46.6	14.0	18.4	110.2

Table 21: Future capacities expected to import coal in 2020. Assumes slippage rates as discussed before.

7 Calculations – Coal requirements, thermal power plant capacity basis

7.1 Coal requirement in 2020

Based on stated assumptions (in the previous sections), projected coal demand in 2020 for thermal power plants only is 898 MT, with ~714 MT coming from domestic coal mining which requires a CAGR of 10.56 per cent till 2020. In addition to assumptions on plant capacities, types, location, etc., we assume a base PLF of 64.46 per cent. This is the FY'14-15 PLF, even though 2015-16 PLFs have fallen. On the other hand, these PLFs are lower than notional or normative (target) PLFs, which are often 68.5 per cent.

Breakup of the numbers is listed in Table 22.

<u>Capacity basis</u>	Coking coal			Non-coking coal			Total	
MT	Domestic	Imports	Total	Domestic	Imports	Total	Domestic (a)	Imports (b)
Steel (+boilers)	34	67	101	1	0	1	35	67
Sponge iron				22	14	36	22	14
Cement				20	14	34	20	14
Fertiliser				3	0	3	3	0
Others				126	0	126	126	0
Power (utility)				714	183	898	714	183
Power (captive)				76	37	113	76	37
Capacity basis (2020)	34	67	101	962	248	1210	996	315
Total							(a+b) = 1311	

Table 22: Calculated coal demand 2020 in MT (based on projected thermal capacity coming online).

The total expected coal demand in 2020 is 1311 MT, based upon assumptions and extrapolations, short of around ~190 MT from the 1.5 billion tonne target. This assumes that imports continue, when in reality one of the stated objectives for 1.5 billion tonnes of production is to eliminate the need to import coal. It is highly likely that coking coal continues to be imported, which we examine in Section 11.1 on (power demand based) sensitivity analysis.

The thermal power plant capacity basis calculation is admittedly on the higher side, because additional capacity anticipated by 2020 in itself is around 70 per cent of the total thermal capacity commissioned till 31 March 2015. The impact of such theoretical but high capacity installation would then likely manifest itself via lower realised PLFs in the future, which does not auger well for the newer plants. Or, some plants, somewhere have to take a PLF hit (assuming PLFs don't fall across the board equally).

8 Sensitivity analysis – Future thermal power plant *capacity* basis

The assumptions used for calculating coal demand projections for 2020 are base case projections for future; one can get upside/downside values resulting from changes in the assumptions. The following are sensitivity estimates for coal requirements. It is also assumed, unless otherwise stated, non-power demand for coal stays as is.

8.1 Slippage sensitivity analysis

Slippage numbers used in estimates are weighted extrapolations based upon the capacity expected to not be commissioned at the end of 12th Five-Year Plan period (2012-17). However, positive changes in slippage will imply higher capacity coming online by 2020 (unlikely). Varying slippage rate within a range of 50 per cent to 10 per cent would give estimates for coal demand commensurate to the expected capacity online. The current situation of adding copious quantities of RE capacity by 2022 coupled with adverse DisCom situations and virtually no new PPAs being signed does not auger well for new capacity, therefore, it is likely that the slippage rate would be higher than 25 per cent. Hence, at about 50 per cent slippage, worst case scenario, about 83.5 GW capacity would come online requiring about 1,200 MT of total coal at a CAGR of 8 per cent from current supply levels, shown in Figure 6. Also note, the bar in the centre at 25 per cent on the x-axis, is the base case scenario. The graph also shows the CAGRs required to get to the coal projections at various slippages in five years (2015 to 2020).

The actual slippage rates may vary based on the following factors:

- There have been instances in the past of new plants proposed, approved, and commissioned within a time frame of five years. These are positive surprises which reduce the slippage rates, however, a typical time span from conceptualisation to commissioning is around eight years. Such plants impact the slippage rate (read the right end of the graph below, representative of the lower slippage rates).

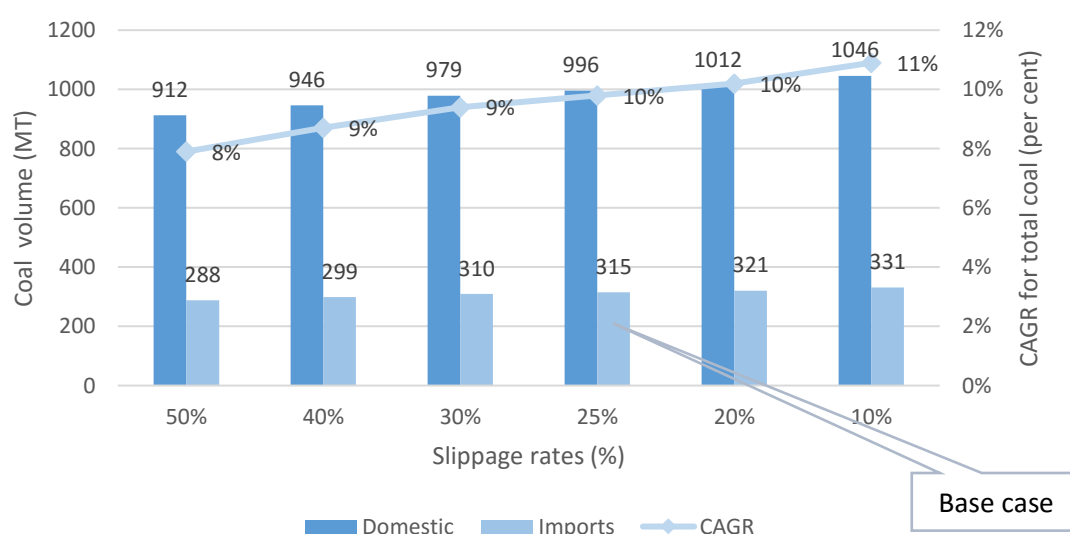


Figure 6: Coal demand [MT] for 2020 with different slippages of power plant construction.

- There are also positive surprises in the form of a few project(s) that lay un-commissioned even after completion due to lack of raw material, unexpected delay in coal linkage/supply or entanglement in legal issues over environmental concerns, getting commissioned in the forecast period (right end of Figure 6).
- A few plants with all the statutory clearances, however, may remain stalled at the end of the forecast period due to adverse circumstances or construction delays such as sponsors' involvement with other projects, or project side-lined for any other reason, contributing to additional slippage to the projections (left end of Figure 6).
- There is high likelihood of less new investment in thermal power capacity unless older plants are retired and new PPAs are signed. The slippage rates are anticipated to be high, based on the current status of the power sector, however, projects already "invested in" would most likely still continue to come up due to sunk costs. The slippage rates, hence, are more likely to be on the higher side, lowering the coal requirement.

8.2 Plant efficiency sensitivity analysis

Technology differences in sub-critical and super-critical power plants make it imperative for coal demand computations to include differences in efficiency values—31 per cent for sub-critical and 38 per cent for super-critical existing power plants and 34 per cent and 38.5 per cent for future power plants, respectively—as parameters to forecast capacity by 2020 on the baseline for the model. Future plants are expected to be more efficient, however, the extent may vary over the base line, seen in the sensitivity analysis (Figure 7).

The difference between existing plants and upcoming future plant efficiencies has been maintained with changes effected only in future efficiencies and not in current efficiencies for calculating sensitivity. Stated another way, present plants aren't likely to change their efficiency much (have less uncertainty). A change of (+/-) 2 per cent for both sub-critical and super-critical over the base line numbers of 34 per cent and 38.5 per cent for future power plants without any changes in current plant efficiencies has been considered. Figure 7 also plots the CAGRs required from the 2015 supply of 820.8 MT in five years to reach the respective total demand(s):

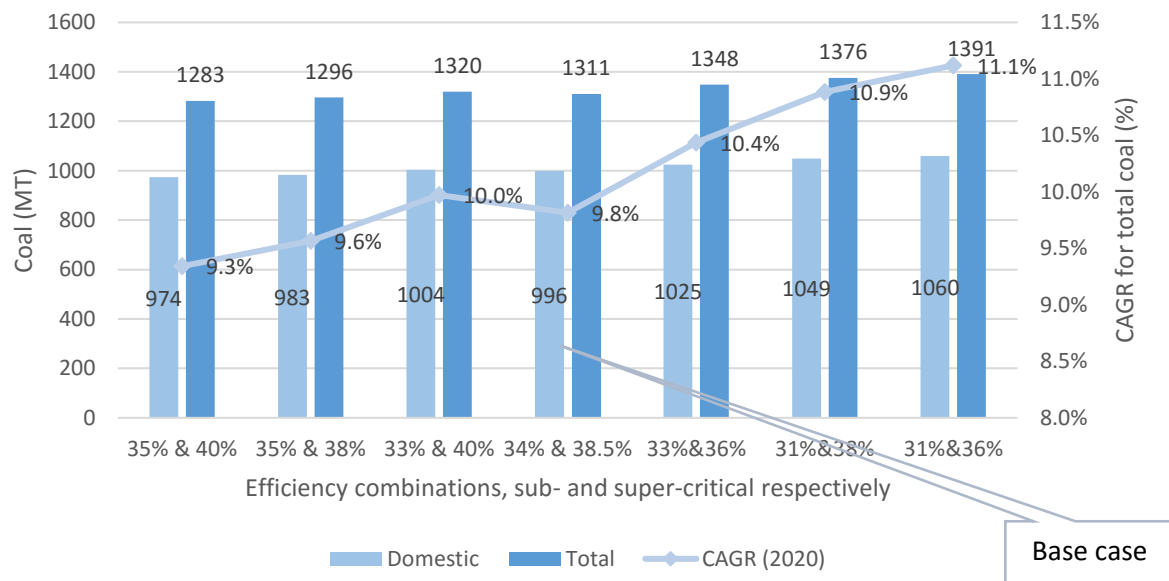


Figure 7: Coal demand in 2020, with changes in future plant sub-critical (per cent) and super-critical (per cent) efficiencies.

As we see above, coal demand decreases from a maximum of 1,391 MT, at higher efficiency values (left side of the graph) and increases towards lower efficiency numbers (right side of the graph), with our base case (in the centre) demand of 1,311 MT. The quantum of super-critical plants being low, the impact on coal demand is not very pronounced.

8.3 PLF sensitivity analysis

Figure 8 shows a trend line for pan-India aggregate thermal monthly PLFs in the last few financial years, clearly indicating a drop in PLF YoY, which could possibly imply that the current capacity is underutilised (there are seasonal variations, of course).

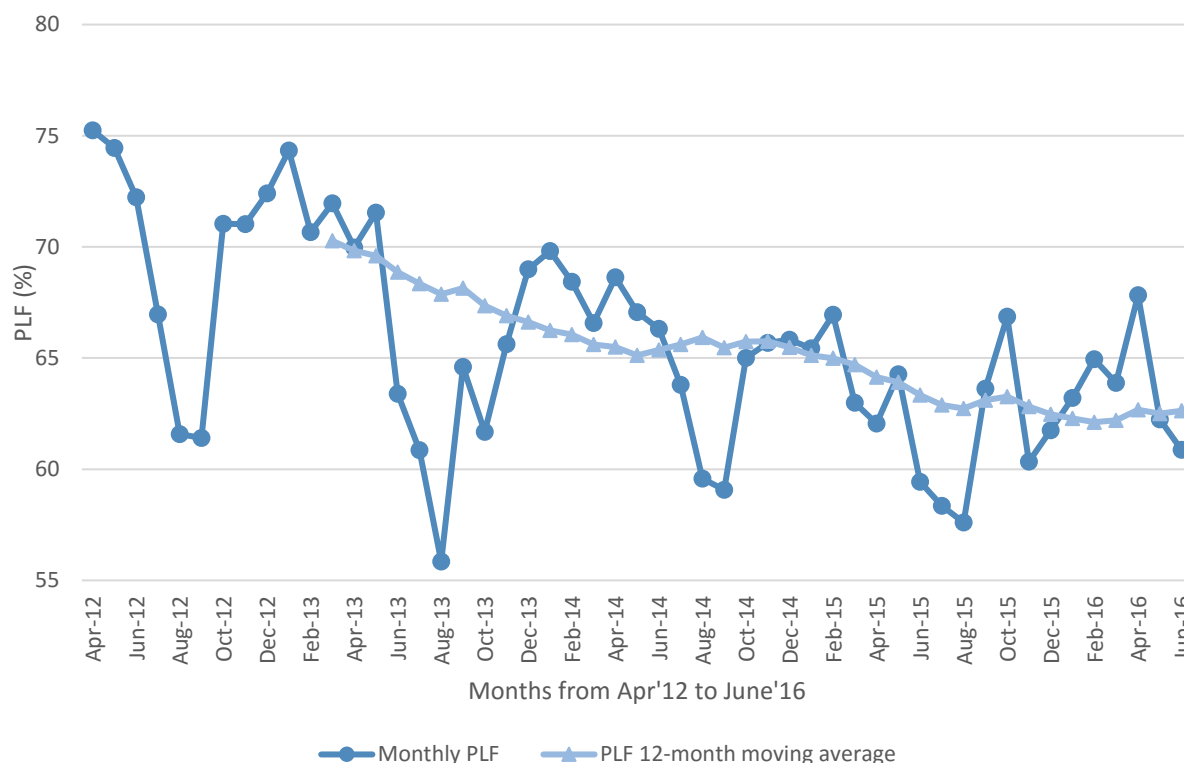


Figure 8: India aggregate monthly PLFs (coal and lignite based plants only). Also shown is the 12-month moving average, to overcome seasonal effects. Source: (CEA Monthly reports March 2012 – May 2016).

Power plants have seen historic PLFs hovering at 75 per cent in the not so distant past. Just a few years ago, shortfalls of coal were a major reason for lower PLFs, but as of April 2016, coal stocks are at a record high.

The recent trend of lower PLFs, without attributing causality, is ostensibly an overcapacity, but there are underlying factors such as reduced demand, rise of alternative power supply, etc. that must be considered.

Low PLFs aren't a steady-state, and a lower PLF could include reduced output from plants instead of just some units switching off, which can lead to lower efficiencies.

Some other possible causes of lowered PLF include:

- Inappropriate and frequent ramping up/down
- Fuel related causes, e.g., variation in quality of fuel, causing the plant to cycle in order to maintain heat rates, resulting in low PLFs
- State-owned plants asked to ramp up if not back down in cases of "excess" supply (non-peak) of RE/central power plants.

Figure 9 is a sensitivity analysis on the coal required as the national (average) thermal PLF changes. The base case PLF for our study is at 64.46 per cent³¹ (marked in deeper shades in the graph) and the graph shows how coal demand responds to changes in PLF, with associated CAGR values for coal growth till 2020 on top of the 820.8 MT of coal demand till March 2015. The range for PLF is taken such that the past PLFs are also represented and the worst case includes the lowest likely

³¹ The PLFs in FY'15-16 was even lower (CEA).

PLFs. As the PLF increases the coal requirement also increase with a 75 per cent PLF requiring high coal volumes ~1,458 MT. A low PLF has implications for plant life through technical efficiency loss and also an economic implication through high cost of maintaining the low levels of PLF, secondary fuel consumption, and a heat rate penalty (Chandra Bhushan, 2015).

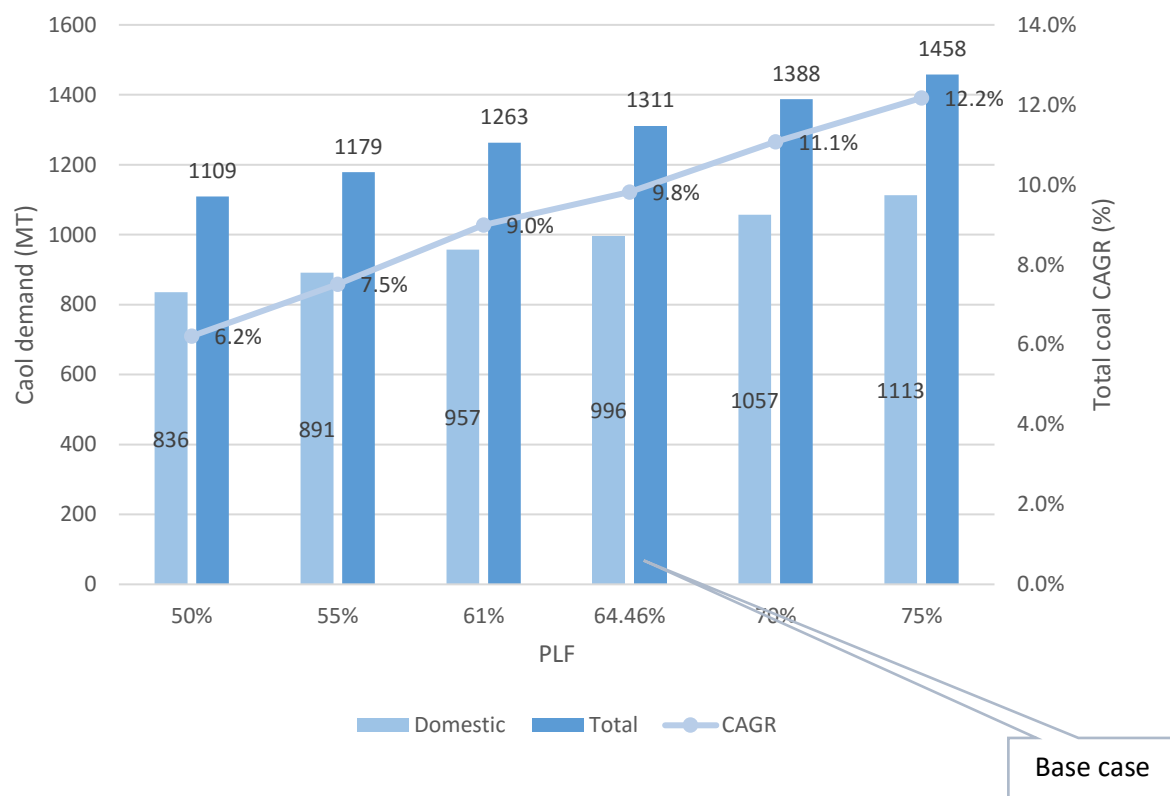


Figure 9: Coal requirements [MT] with PLF sensitivity of power capacity expected by 2020. This assumes the capacity is built as previously calculated but is able to operate at different PLFs.

9 Assumptions for energy demand projections in 2020: A limiting factor

Till now, we have focused on the supply of power through coal powered plants. What about demand for coal-based power? Demand for coal-based power is a subset of total demand for power, factoring in alternative supplies. While most alternatives have had modest or even low growth, Renewable Energy (RE) has seen dramatic increases in the last few years, even before considering the enormous 175 GW RE capacity targets of the government by 2022 (almost a five times growth in seven years!) The targeted increase in total installed capacity from all of these sources by 2020 raises an important question: would India be able to absorb all the energy coming online, including 110 GW³² coal based after slippage, at the current PLF of 64.46 per cent and if not, what are the implications?

9.1 Assumptions for calculating electricity demand in 2020

To answer the above questions, we extrapolate the total increase in demand (BUs) by the year 2020. In 2015, Indian power demand was 1049 BU. We segregate demand growth into various buckets as organic growth and inorganic growth. The former is GDP-related, and factors in all growth as we've seen thus far. However, given ~300 million people still do not have connections to the grid (O'Neill, 2016), and we still have shortfalls of power in places (load-shedding), we can estimate such one-off growth in demand assuming these problems are solved by 2020. From a modelling perspective this is inorganic growth, as it is one-off and above-and-beyond existing demand growth.

9.1.1 GDP elasticity of electricity

Economic (GDP) growth is linked and correlated to energy (power) use, but the linkage is not static or simple. First, we have changes in the economy, with services demanding less energy than manufacturing. Second, we have the push towards energy efficiency, notably in lighting (LEDs) and efficient appliances. Third, we have issues of time lags, where GDP growth percolates to new investment.

For India energy intensity has been falling since 1981 (Planning Commission, 2012), following a general pattern for the development ladder. For the purposes of this analysis, we have chosen a single base value of power demand to GDP growth elasticity of 0.9.

From an energy perspective the aggregate values for GDP elasticity of primary energy (not electricity only) have been decreasing, from a value of 0.73 in 1980-81 to 0.66 at 2000-01 (Planning Commission, 2012). Considering electricity only (see Figure 10), for the analysis we have chosen a single baseline value of 0.9 as the GDP elasticity of electricity. A simple multiplication with GDP (assumed 8 per cent) gives us a value of 7.2 per cent organic growth of electricity demand.³³

³² The total is 115 GW however, 5 GW has already come online since the start of the study.

³³ Simple regressions do not provide accurate estimates given standard regressions assume independent, identically distributed variables. Examination of the data indicate periods of negative auto-correlation (high elasticities are often followed by low elasticities), in addition to a trend that isn't normally distributed (as GDPs rise, the elasticity doesn't necessarily rise as much, in part (possibly) due to the contribution of the service

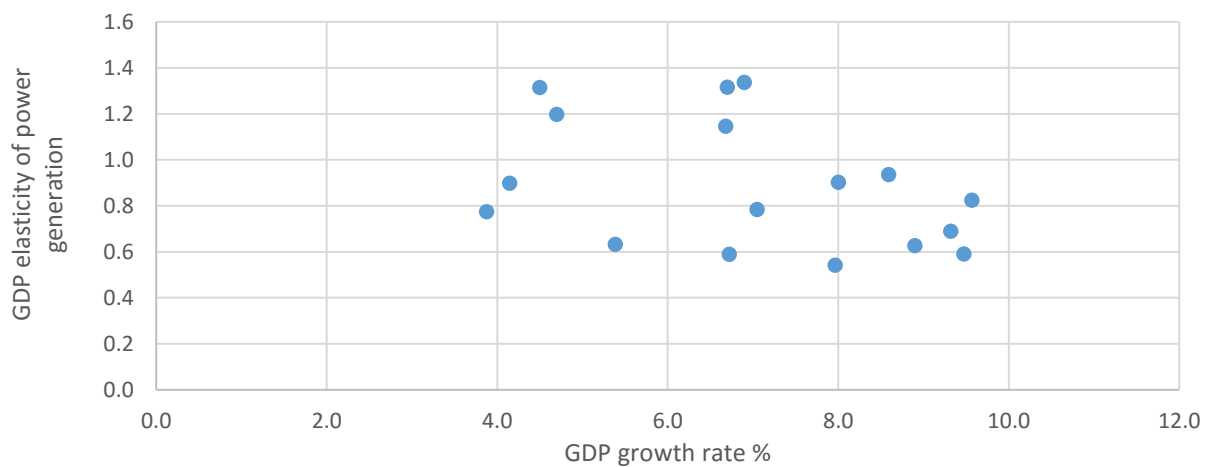


Figure 10: GDP Elasticity of Power Generation Vs GDP Growth Rate (1998 – 2015). This is based on MoP/CEA data for generation (BU) and Ministry of Finance data for GDP.

9.1.2 Meaningful electrification for households (especially new connections)

Meaningful electrification goes beyond the first step of putting up supply lines till the village/supply region. Tongia (2014) suggests this to mean actually connecting *households* with the supply lines and assuring a minimum *quality* of service levels. Ideally, zero load-shedding, starting with the peak demand periods (evenings are critical for households).

For our study, we assume that new connections would have a low value of demand as these households are newly electrified, and also typically link to lower socio-economic strata of society. For the sake of simplicity, we have taken the consumption from these households at a baseline of approximately ~ 500 units per annum.

9.1.3 Removing all load shedding

The third important factor contributing to future electricity demand is fulfilment of latent demand. Improvement in quality of supply – consistent voltage and zero load shedding – is of equal importance, if not more, to reduce the implicit costs associated with low quality power supply (frequent repair of equipment and cost of alternatives for coping with power cuts). The latent demand is estimated at around 3.6 per cent of the total estimated demand (~1,110.2 BU in 2015).³⁴ We have assumed that this would be reduced gradually and by 2020 this would amount to zero, however, the plugging of shortfall would also generate an additional demand in the form of increased use of appliances due to improvement in quality of supply.

sector.) Other factors that matter include the strength of the monsoon, any growth in manufacturing, global impacts for GDP, and time lags between investment, operations, etc.

³⁴ These estimates are from CEA's Load Generation Balance (LGB) reports, which might slightly understate the shortfall. In the absence of proper instrumentation, shortfalls are "as-reported" by states.

9.1.4 Reduction in technical losses

The last factor that has been taken into account to calculate the total electricity requirement in 2020 is the reduction in *technical* losses. While much of the total losses of roughly 20 per cent (just at the distribution level, termed AT&C, or aggregate technical and commercial) are non-technical, even technical losses are high in India, due to phase and load imbalances, long feeder lines, lack of reactive power support, etc. So-termed commercial losses are still consumed, so a reduction of the same may improve finances, but still require generation (unless such demand vanishes). We assume that there is an annual improvement from 2015 in technical losses by 0.25 per cent initially, falling to 0.05 per cent, annual technical losses improvement, in 2020.

9.1.5 Displacement by RE

In the base case for the model, it has been assumed that there is no net displacement of thermal BUs by RE based generation. This is conservative from a coal requirement perspective, and we subsequently factor in a small and gradual displacement of 1.5 per cent of thermal BUs by RE based generation (by 2020). If, and this is an unknown, India reaches 175 GW of RE, and this operates on a “must-run” basis (never backing down RE), then even with a growth of coal and other sectors, the relative share of RE grows by much more than 1.5 per cent (see Figure 14). RE integration and subsequent coal displacement has been dealt in much greater detail in Section 13.3.

10 Calculations: Coal requirements, electricity *demand* projections basis

10.1 Energy demand projections in 2020

The above assumptions when used to calculate the future BU in 2020 give a value of 1,634 BU. This value amounts to a CAGR of 8.04 per cent in the electricity demand between 2015 and 2020. However, this number is source agnostic, meaning for calculating the BUs from thermal power plants we assume a constant ratio (between 2015 and 2020) for generated power (electricity) from all sources. Keeping today's 79 per cent thermal power generation in 2020, we get a number of 1,291 thermal BUs, with a similar share for coal within the thermal group.

10.2 Coal required for energy demand in 2020

Using the above value of power demand in 2020 the coal required to achieve this demand level would need some additional assumptions:

10.2.1 Other assumptions

- Thermal power from coal is still generating 79 per cent of total power in 2020, hence, discounting any displacement of thermal power due to uptake in the renewables energy projects till 2020 (which may not be the case, and a sensitivity has been added for this, refer Section 13.3).
- PLF and efficiency values are the same, as used for power capacity calculations in the earlier segment, and so is the coal leakage, non-power sector coal requirement, and imports. All these calculations remain as used in the coal based generation capacity calculations in Section 6.

Based on the assumptions above, coal required by 2020 to suffice energy demand is calculated to be 1,228 MT. Breakdown of the demand is given in Table 23.

<i>Demand basis</i>	Coking coal			Non-coking coal			Total coal	
[MT]	Domestic	Imports	Total	Domestic	Imports	Total	Domestic (a)	Imports (b)
Steel (+boilers)	34	67	101	1	0	1	35	67
Sponge iron				22	14	36	22	14
Cement				20	14	34	20	14
Fertiliser				3	0	3	3	0
Others				126	0	126	126	0
Power (utility)				648	167	815	648	167
Power (captive)				76	37	113	76	37
Elec. demand basis (2020)	34	67	101	895	232	1128	929	299
Total							(a+b) = 1228	

Table 23: Total coal demand (based on power demand as the limiting factor) by 2020.

Given the demand basis calculations for power lead to a lower requirement than from a coal plant capacity basis, this is a more realistic figure given demand is the bottleneck. Even if more capacity comes on line, if the demand isn't present, this means lower PLFs. Thus, this mechanism (power demand basis) is the chosen method for the bulk of the sensitivity analysis (unless stated otherwise).

11 Sensitivity analysis: Future electricity demand basis

The assumptions used for calculating power capacity and demand by 2020 start with the base case. However, one can vary these assumptions and get upside/downside values. Following are the sensitivity estimates for coal requirements:

11.1 Sensitivity analysis - imports

India imported ~212 MT of coal in FY'14-15 which included ~43 MT of coking coal for steel manufacturing and ~125 MT used in non-captive thermal power plants, and ~26 MT in captive thermal power plants, whereas ~17.4 MT coal was imported for non-power application. Thermal coal sector imports are required for following reasons:

- Blending with domestic coal to achieve higher average GCVs, at lower ash content, to match the thermal units fuel quality specifications
- For thermal power plants that are close to ports, inland transportation of domestic coal is usually an expensive proposition. The coastal power plants may prefer to import since,
 - (Like all plants) the quality of coal is better: higher average GCV and lower ash and moisture content
 - The savings on transportation costs vis-à-vis inland transport of lower grade coal. The average transportation cost being 846 INR/tonne for an average distance of 620 KMs (Chandra Bhushan, 2015). Global coal prices are also low, for various reasons.

In discussions with experts, they also gave anecdotes that some plants are optimised for specific coal, which goes beyond notional guidelines of quality.

11.2 Future import scenarios

Scenarios for imported coal and impact on total domestic coal production have been considered, based on changes in the following assumptions:

- Imports to maintain the same percentage share of the total supply as in FY'14-15 (this is the base case), due to quality concerns with domestic coal (high ash and low GCVs) and ease of transportation and consumption at the coastal power plants
- Some newer plants may have been built to specifications that require imported coal or at least some blending with imported coal
- Coking coal imports are most likely to continue as is, considering the low domestic reserves of high quality coking coal.

In this sensitivity analysis, the baseline is less a middle value than a bound since, realistically imports are likely to fall due to improved domestic availability.

Working on the above base case, a number of import scenarios ranging from partial import substitution to zero imports have been summarised below in Table 24 and Table 25. Please note:

all of these calculations are on top of the estimates of coal required (MT) for estimated power demand (BUs) in 2020.

Scenarios		Import (MT)	Residual compensated by domestic coal (MT)	Total (MT)
a	All Imports grow to remain same percentage share [Base Case]	299	929	1228
b	50 per cent import reduction by share for power sector	215	1036	1251
c	No Imports for Power	132	1142	1274
d	50 per cent import reduction by share for non-power sector and no imports for power	81	1207	1288
e	Only coking coal imports	67	1225	1292

Table 24: Different scenarios of imports and their effects on domestic coal requirements (million tonnes).

This factors in the difference in coal quality (from a calorific requirement, one tonne imports is worth more than one tonne domestic coal).

Note, that changing imports doesn't just affect the domestic component but overall demand as well given the difference in heat values of imported vs. domestic coal.

Scenario a (Base case):	Import demand calculation is based on maintaining the same percentage share of total demand as it was in 2015
Scenario b:	Calculation of Import for non-power sector is based on GDP growth rate of 8 per cent on 2015 coal import numbers and a reduction in imports for power sector by 50 per cent of its percentage share in 2015
Scenario c:	No imports for power sector imply a total import substitution for power sector imports by indigenous coal. While the coking coal imports and other sector imports grow as anticipated their GDP elasticity adjusted respective growth rates of (9 per cent for coking coal, taking into account the GDP elasticity of coking coal industry 1.1)
Scenario d:	50 per cent import reduction for non-power sector calculated on base GDP growth rate (8 per cent) and no import for power sector
Scenario e:	Coking coal is mainly required for steel industry which has projected growth rate of 9 per cent based on 1.1 elasticity over GDP growth rate, those are the only imports in this scenario.

Table 25: Details of various imports scenarios.

The scenarios for import reduction in the future are shown in Figure 11. As discussed, while some level of imports reduction are likely, the actual modest reduction in imports in FY'15-16 (~12 million tonne reduction YoY (MJunction, 2016)), when domestic supply was a not a bottleneck anymore, suggests non-coking imports will *not* decrease to ~zero.

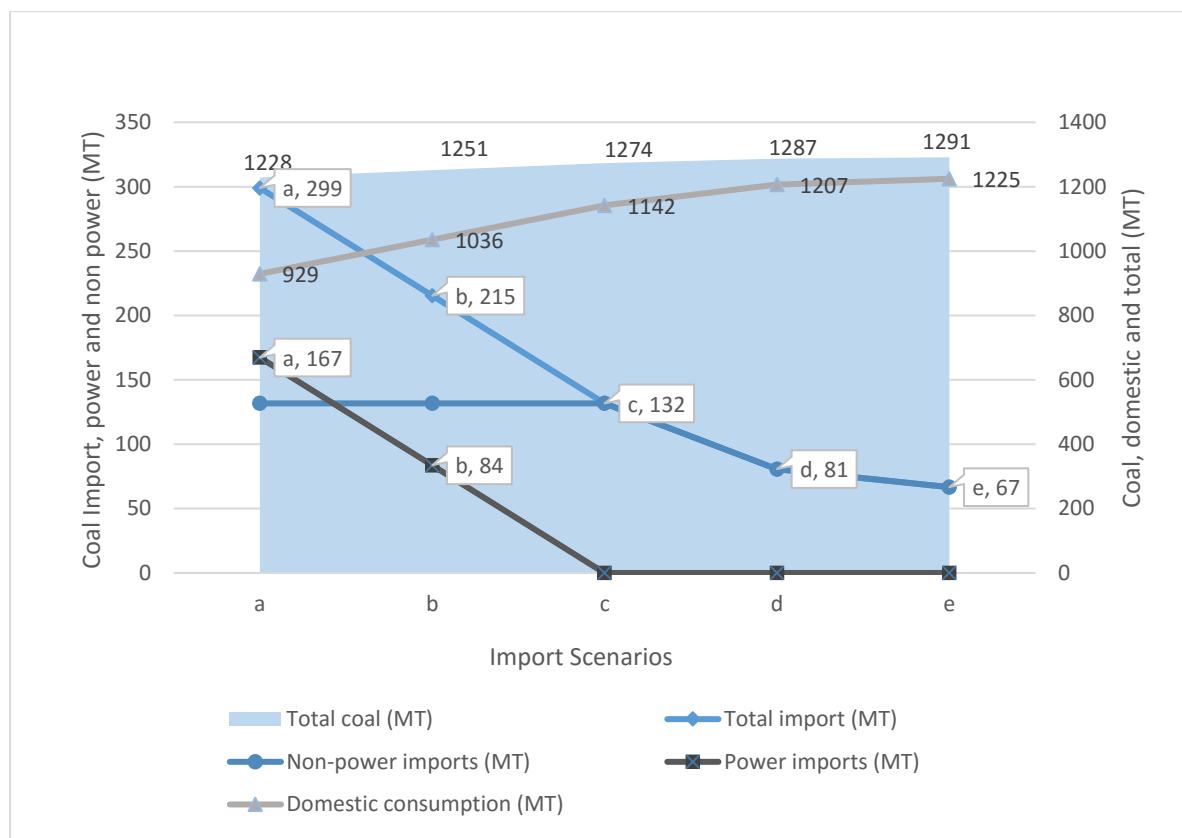


Figure 11: Imported coal scenarios and their impacts on total domestic coal requirements. This is based on power sector demand as the limiting factor. The area under the curve is boundary of the total requirement.

11.3 GDP sensitivity

GDP is one of the key impact variables that changes the total coal demand. With a base assumption pegged at a high of 8 per cent GDP growth rate for the next five years, any changes in GDP (decrease) reduces the coal requirement as well. A 1 per cent (absolute) reduction in anticipated GDP growth rate reduces the coal requirement in 2020 by about ~4 per cent, as shown in Figure 12.

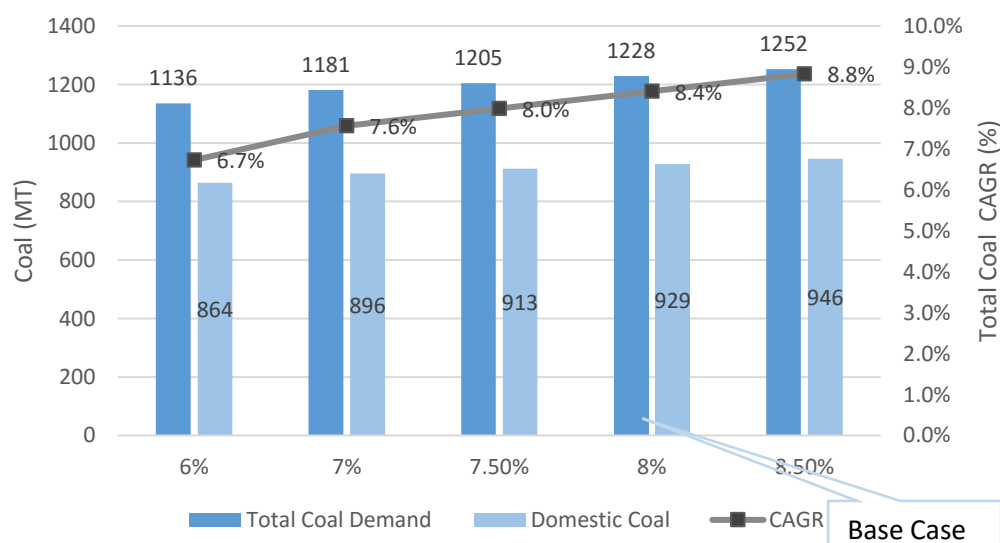


Figure 12: Impact of GDP sensitivity on coal requirements.

12 Triangulation: Power demand and future capacity throw up divergent coal requirement numbers

12.1 Coal demand (Thermal power capacity v/s power demand)

Coal calculation through power capacity expected online by 2020 and through power demand calculations by 2020 throw up two contrasting numbers with separate CAGRs, Table 26.

Domestic coal for future power <i>capacity</i> 898 MT	Domestic coal for future power <i>demand</i> 815 MT
<ul style="list-style-type: none"> Base capacity scenario for power sector gives a total coal requirement of 1311MT on the following assumptions (base case) <ul style="list-style-type: none"> GDP growth of 8% Imports maintain same share of total supply GDP elasticities for non-power sectors PLF 64.46% (CEA, September) (CEA, CEA Monthly Executive Summary Power Sector, April, 2015) 31.1% efficiency for existing sub-critical plants and 38% for super-critical plants The average coal type is G11 and respective GCV was used 4% leakage of coal was applied. Total required coal CAGR of 9.8% 	<ul style="list-style-type: none"> Base demand growth scenario for power sector gives a total coal requirement for 1228 MT calculated on the following assumptions (base case) <ul style="list-style-type: none"> New consumers at ~500 units per annum GDP growth of 8% GDP elasticity of electricity = 0.9 (organic growth of 7.2% in power demand) 100% electrification, 3.6% latent demand and additional demand of 1% by 2020 Reducing AT&C losses in line with global value of 0.05% by 2020 No RE displacement (in base case) Total required coal CAGR of 8.4%

Table 26: Comparative analysis of coal required for power capacity and power demand in 2020.

Total coal required by 2020 based upon capacity projections is 1311 MT, of which 996 MT is expected to be satisfied through domestic production, whereas, 315 is expected through imports. The same numbers change based on power demand calculations in 2020 and 1228 MT of total coal, of which 929 MT is domestic production and 299 MT of imports, is required conditional to demand assumptions holding true.

12.2 Implications of power supply-demand mismatch on PLFs

The power supply-demand mismatch, can lead to a reduction in the PLF's of the operational plants to manage low electricity offtake, which in turn would affect the efficiency, increase carbon emissions and reduce life of plants (due to frequent cycling up/down of the plant). However, there is a difference between the older and the newer plants in operation. While the older plants have lower cost of power generation (as they are completely depreciated or higher depreciated, relatively speaking, against the newer ones), the newer plants have sunk costs and thus a higher cost of power generation. Lower PLF's for such plants, especially when the accounting is based on

a nominal value of 85 per cent PLF, increase the payback period and reduce the returns on newer capacity. Thus, the upcoming plants should not be expected to run on low PLFs as it is technically and economically inefficient. What are the ways then to maintain higher PLFs for such plants?

One of the ways to maintain higher PLFs for the newer plants is to retire the older ones. However, this would impact the total capacity and supply available. It is also worthwhile to note that, marginal cost of power from these plants is low hence, shutting down these plants can raise the average price of power to the consumer—a political hot potato.

Another way is by limiting the production from the newer power plants (or even upcoming plants) however, this is an inefficient solution, as the new(er) plants will have better technology and lesser environmental impact compared to old(er) plants

In the absence of data, we don't know what the PLF of older plants is versus the newer ones. If the older plants, with lower efficiency values down to 21 per cent (much lower than the average values of 31 per cent pan India) already have a lower PLF, aggregate saving of coal by reducing the output from such inefficient plants is diminished.

Figure 13 indicates the impact on the PLFs of older plants on running the newer plants on higher PLFs while keeping the total generated electricity (BU) constant.

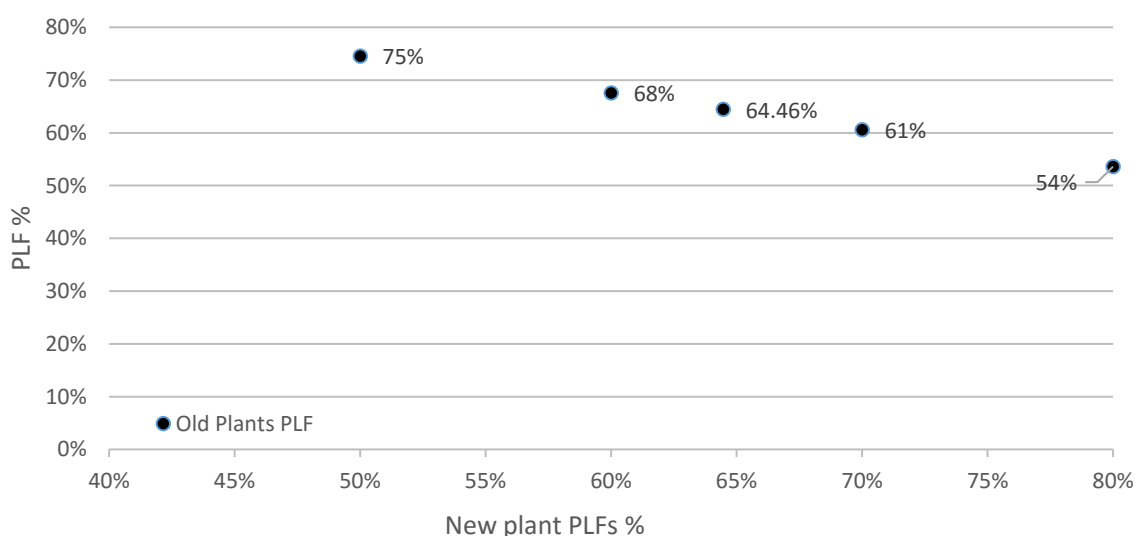


Figure 13: Displacement of PLF of older plants due to higher PLFs of newer plants. The FY'14-15 PLFs are 64.46 per cent, and the aggregate system PLFs have fallen to nearly 60 per cent by 2015-16.

To summarise, whichever way one looks at this, an excess capacity would constrain the growth and feasibility of future power plants, that is, without even considering the proposed significant capacity addition in the RE (renewable energy) sector, reducing the prices of electricity in the hands of consumers and exerting pressure for downward revision of power tariff on the producers. The implication could be reduction in planned expansions and looking for cheaper fuel options to reduce costs. This would directly exert pressure on CIL and to reduce coal prices, perhaps renegotiate the linkages, etc. which would benefit the older power plants as well, effectively negating any transfer of benefits to the power consumers. In a nut shell, this mismatch would push

the thermal power sector to adjust to a lower price realisation and make power sector investments risky, possibly impacting the banking industry by an increase in the NPAs.

12.3 Impact on coal

Even an optimistic estimate of power demand (non-power sector being the same) fails to throw up a coal requirement close to 1.5 billion tonnes. It is also likely that demand growth is limited at the current growth rates, the GDP grew by 7.6 per cent in the financial year 2015-16, and the coal requirements do not exceed 1,200 MT in total in 2020, in which case around 913 MT of coal would be required from domestic sources, considering similar export ratio, and more in case the exports are reduced. There is the need to increase coal production in the short run and there will be pressure on CIL for bridging any shortfall. Although there are limits to CIL's capacity augmentation as well, it needs to be realistic in terms of how much it can produce. However, opening up the mining sector for private participation can ease the pressure on CIL only in the longer term (not in the short term – 2020), as incremental measures³⁵ have not yielded desired results. The targets need to be re-thought considering the actionable and achievable in order to prop up demand by 2020.

³⁵ The recent policy announcement of centralised allocation of coal linkages to the respective state governments for onward distribution to power plants in the states is expected to improve the system efficiency. If this reduces costs and thus increases demand, it could increase the coal requirements. However, it is unlikely that marginally lower costs, even if achieved, are the key factor for increased demand of coal. On the other hand, efficient use of coal involves using more efficient plants better (at a higher PLF), and such flexibility could reduce coal requirements, in addition to savings on transportation costs.

13 Discussion: Robust calculations for lower coal requirements

The target of 1.5 billion tonnes of domestic coal by 2020 isn't only ambitious from a supply perspective, it risks being far higher than the likely offtake which could be several hundred million tonnes lower, depending on the quantum of import substitution. It would, however, be prudent to examine what supporting infrastructure would be required to facilitate greater availability of coal.

13.1 Can an increase in washery capacity reduce quantum of imports?

The question of more washeries installation to upgrade domestic coal quality is controversial. The current domestic washery capacity is ~131 MT, (Chandra Bhushan, 2015) with only about 77.19 per cent being utilised (Press Information Bureau, 2015). The utilisation of washery capacity is complex as not all washing is of the same type, and the technology of washing maps to the actual coal type that can be washed. Additional upcoming washing capacity, 115 MT in total and 15 in number of which six are for coking coal and nine are for non-coking coal, would increase the washing capacity. However, the offtake depends on factors such as logistics, contracts, etc. In addition, use of dry washing should be encouraged (technology like Ramdars) to ensure lesser water consumption and environmental load. Washing also impacts the quality of coal increasing the moisture content, and reducing the density in addition to the following issues;

- Washing is an additional cost to the value chain, which needs to be borne by the end consumer. A market for this value added product is far from developed.
- Distance of washery from the mine and the plant determines the increase in transportation cost payable, which in many cases may be higher than the cost of washing.
- Washing generates rejects, which have high ash content and are generally unusable in large industries. Disposing off these rejects in an environment friendly manner needs to be addressed.
- From an environmental stand point, it is pertinent to ensure the water used for washing is reused or treated before disposal in order to avoid negative externality or use dry washing. Newer plants operate on closed-loop cycles to a large extent.

To ensure availability of washed coal the associated technical issues with washing and waste disposal along with rationalised tariff structures for transportation are necessary. Without such structural changes in coal washing future plans for increased utilisation of washed coal could remain stillborn without any improvement in utilisation of the existing capacity.

13.2 Low transportation capacity could be an issue?

One of the key enablers for coal movement in the country is railways. There are bottlenecks in the form of steep tariffs, last mile connectivity problems (necessitating trucking), losses and pilferage enroute, and choke points causing delay on some of the busiest routes. However, railways remain, and are expected to remain, a major enabler for coal movement in the forecast period. The steep increase, if not 1,500 MT but a lower value of domestic transport of at least 929 MT through 996

MT, would need a commensurate capacity upgradation for the railways as well. This would either be, adding additional wagons for movement or mandating rapid loading/unloading methods for the consumers to minimise loading/unloading time at the siding.

Mode of transportation	Share per cent (of quantity of coal transported in MT)
Railways (Including rail +sea)	56%
Road	24%
MGR	18%
Belt conveyors+ ropeways	2%

Table 27: CIL modes of coal transportation. Source: (Ministry of Coal, 2014-15)

The current mining of CIL at ~520 MT of coal could double up in the next five years, and even if 50 per cent of this coal is transported through railways (assumption) this implies 250 MT of coal movement on the railways currently. If somehow CIL reaches 1 billion tonnes, then an additional 250 MT capacity could possibly come online, which is likely to be at remote locations with distant railheads assuming schedule I mines would be producing. To move coal from these locations to the end use plants is a challenge which cannot be accomplished without optimising the railway fleet by adding new capacity, both in terms of new routes and wagons. Without an upgrade of routes, tracks, and wagons, coal mining (driven by utilisation) may not be able to achieve its targets even if new mines are able to produce the requisite quantities on time.

The current transportation tariff is heavily loaded in the favour of railways, with higher charges for volumetric load and washed coal. There is also pilferage in certain sections which is a cost for miners—in our calculations an overall 4 per cent aggregate pilferage loss, quality losses, and self-combustion has been assumed. There needs to also be a rationalisation of the tariff contingent to service levels quality to ensure that railway transportation remains relevant and competitive. It is of utmost importance to address structural concerns in the railways, including creation of dedicated freight corridors, to enable cost-effective coal mining targets till 2020 (Mohan, 2001).

13.3 RE integration

Integration of RE is one of the key impact variables reducing the quantum of thermal power generation and thus reducing the need for coal, not as much because of its magnitude but because of the great uncertainty in RE contributions plus level of displacement of existing generation. Given that the current and projected peak demand is in the evening, solar power isn't likely to contribute to the peak, and thus there is a greater chance of displacement of PLFs of other sources (including coal).

With an ambitious target for RE by 2022, it is possible that some displacement of thermal BUs would happen with the increase in RE generation. At a 19 per cent PLF (annual aggregate), and expected RE capacity increase at 22 per cent CAGR by 2020, the total installed capacity by 2020 could reach 106 GW resulting in a generation of about 176 BUs. This 10.8 per cent share of RE would imply a displacement of other power, especially coal (Figure 14).

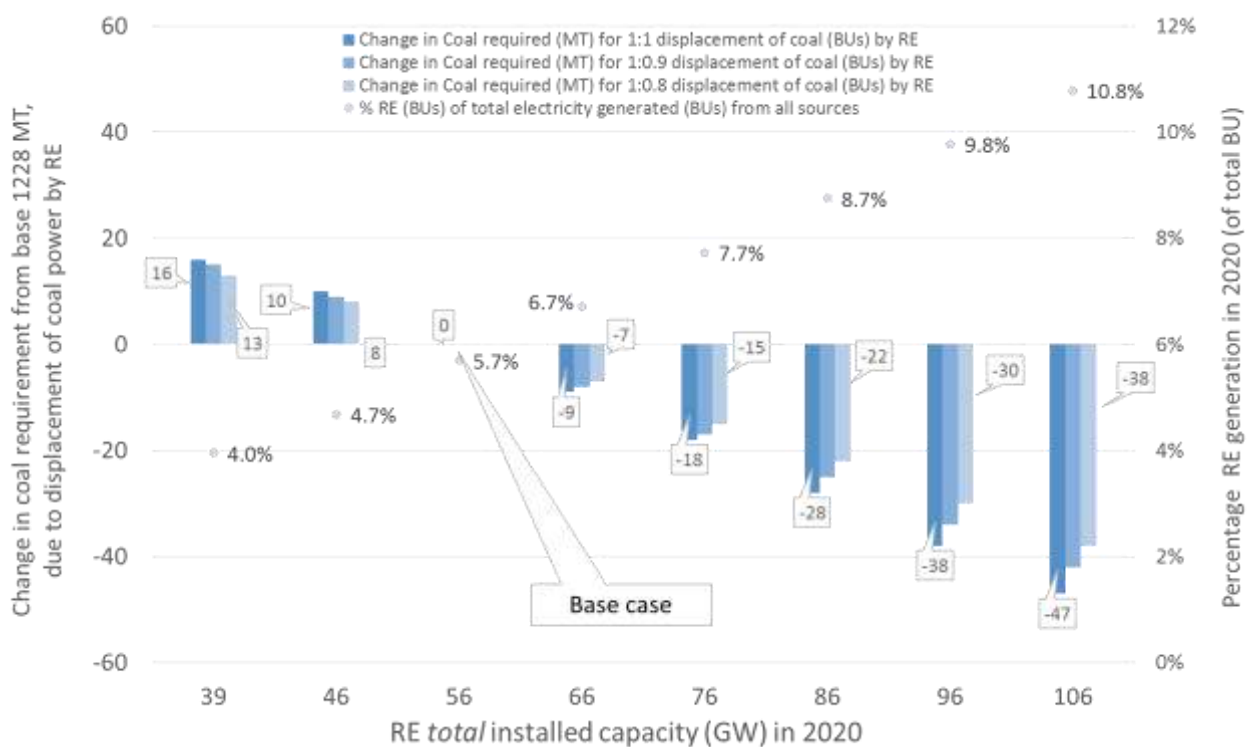


Figure 14: Impact of RE displacing coal demand in 2020 based upon various RE capacity achievements by 2020. The 2022 target of 175GW implies the need to reach 106 by 2020, which would increase the RE share of total projected electricity (BUs) to 10.8 per cent.

We find that for different total RE capacities by 2020, starting with effectively zero growth (an academic exercise) to 106 GW by 2020 (the required amount to reach 175 by 2020 at a steady CAGR) the share of RE generation in BUs can vary measurably. The FY'14-15 share could stay constant (the marked point) but realistically there will be a growth (converting capacity to BUs @ 19 per cent PLF for RE). Such increased RE could displace coal BUs at varying levels, from 1:1 to perhaps less, assuming other generation also backs down in favour of RE. It is unclear how this will play out, as it depends not just on costs but marginal costs, as well as time of day issues. Thus, we find a potential for the reduction of tens of millions tonnes of coal with higher RE—not enormous but still measurable.

Integration of RE would continue to remain one of the biggest challenges and a wild card that could impact coal demand in 2020. Growth of RE depends not just on financing such capacity or even grid integration, but also on the growth of ancillary services in the power sector (systems to help keep the grid stable), storage technologies, smart grids (which can help control demand), etc.

13.4 Implications – 2020 and beyond

13.4.1 Do two wrongs make a right? No easy “bye” for CIL

This analysis shows that 1,500 MT of domestic coal is a very, very high target, and more than necessary. However, this doesn't mean reduced pressure on CIL for rapidly growing output. Of the 1,500 MT, 1,000 MT is to come from CIL, and the remaining 500 MT from private (captive) miners. This means that CIL has growth targets of 15 per cent between 2015 and 2020, while the private

sector has 61 per cent CAGR requirements. Given the private sector produced only half of their targets in FY'15-16, we believe the private sector will fall disproportionately short of their 500 MT targets, leaving the bulk of the pressure for output on CIL.

13.4.2 Other implications of a target mismatch

If one simply finds a shortfall in coal production, this would not, in and of itself, be a major challenge. Many targets are aspirational or ambitious, and market conditions determine what is really feasible if not desirable. However, targets guide investments and there is the risk of crowding out investments in areas of prime importance for India's power sector.

Today's shortfalls of power are at a record low (on a percentage basis), but that doesn't mean there is zero load-shedding, especially in pockets and/or certain times of the day and year. The main challenge for India in the coming years is cost-effectively meeting the peak demand. This is something that will not be solved by coal power nor solar power. India's peak demand is presently in the evenings at a national level, and sometimes in the morning.³⁶ This problem will only get worse as we grow RE, which helps with generation (kWh) but much less so with capacity (kW). This must be seen in the context of the true policy targets, which aren't coal per se but affordable power for all, 24x7.

The international commodity market down cycle has provided an interesting opportunity for India to put its coal mining sector in order. Historic low prices mean imports, if chosen, would reduce foreign exchange outflow. More importantly, these put pressure on domestic production to be efficient and competitive. However, to make itself self-sustaining in the long run the sector needs to disentangle the mining sector from end use plant based constraints, and likely open up commercial coal mining to private investment (which brings both capital and technology). One can make railways a stakeholder in the coal targets, investing part of the environmental/clean cess into transportation capacity augmentation.

Railways have 87.6 per cent of revenues from freight, which cross-subsidises passenger traffic. Of this, 46.5 per cent comes from coal. With aggressive targets for domestic coal production, this has specific planning implications for railways which may find itself facing underutilised or non-optimal routing of tracks and/or traffic. This wouldn't be the first time this has happened—in the power sector aggressive capacity targets for generation often fell short while transmission lines would sometimes come online as per schedule.

The last set of implications are financial. First, we believe that reductions in coal output will come disproportionately from captive users, who (a) have alternatives such as CIL/e-auction/imports; (b) may find the prices as bid³⁷ to be untenable (relying on alternatives).³⁸ If they do choose to reduce outputs (with an extreme step of forfeiting their deposits), this would impact public revenues expected from the auctions process. Second, given the strong risks of under- or non-performing

³⁶ This is assuming storage technologies are still expensive, which is likely the case in the coming few years at least on a large-scale energy arbitrage basis. It already has disproportional value in limited and niche uses including balancing, ramping, etc.

³⁷ The bid refers to the recent coal block auction winning bids, based upon which the winner of the block has to pay a per tonne levy on the coal mined. In case not able to pay then they lose the bank guarantee and also the block.

³⁸ In addition to alternatives for coal, there are macro issues on end-product demand which may influence end-user decisions on how much coal to mine.

coal power plants, there are banking and finance risks for some plants. If we “only” find a reduction in PLFs, this may not quite mean a run on the banks (assuming debt is only 70 per cent of a project) but the equity holders would certainly be staring at a haircut at the very least.

14 Appendix A

The provisional coal statistics from the MoC (Coal Controller Organization, 2016) and the Annual Coal Report of the MoC (Ministry of Coal, 2015) do not reconcile in some of the coal data with independent sources like IndiaStat (IndiaStat, IndiaStat, 2016). The coal supply numbers were finalised upon collating from various sources, and triangulating with experts in this sector, to get the best estimates of coal imports (in specific sectors). The data usage protocol is explained below:

- Segment wise indigenous supply is as reported in the MoC provisional coal statistics.
 - For coking coal; both indigenous supply and imports, are as reported in the provisional coal statistics.
- Coal imports for power (utility) are estimates based upon inputs from multiple data sources like MoC (Coal Controller Organization, 2016) and IndiaStat (IndiaStat, Indiastat, 2016) and subsequent triangulation with experts.
- Coal imports for power (captive) are hard to find, since CEA monthly report on power sector does not capture or report any data on captive plants except for an installed capacity of ~40 GW (CEA, CEA Monthly Executive Summary Power Sector, April, 2015). The volume of imports for captive power plants estimated in the table above (26 MT) assumes blending requirements necessitating imports, the quantum of blending is typically ~30 per cent imported coal in the coal feed. However, there are thermal capacities, difficult to segregate, running purely on imported coal as well, underscoring the difficulty in exact calculation of imports for captive power plants. Hence, an assumption of imports for this sector is used primarily based on the quantum of indigenous coal made available to captive power plants in FY'14-15, and triangulation with experts in this sector.
- Sponge iron and cement are two important sectors that import coal. However, they indicate divergent numbers for coal use based on different databases. To distribute imports among the two, the base of no substitute for coal in the sponge iron industry whereas cement industry's growing use of alternative fuel sources like the pet coke was considered. Hence, sponge iron's coal demand was given primacy before attributing any imported coal to the cement industry. Once the sponge iron coal requirement (based upon projected demand) was fulfilled the residual imports (after allocations to various sectors) were adjusted in the cement³⁹ sector.

³⁹ The actual usage of coal in cement is on a downtrend and could be even lower, any future coal usage projections in the cement industry should be read with this disclaimer.

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