2013

Report of the Working Group on Integrated Strategy for Bulk Transport of Energy and Related Commodities in India

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National Transport Development Policy Committee (NTDPC)

Report of the Working Group on *Integrated Strategy for Bulk Transport of Energy and Related Commodities in India*

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Preface

The National Transport Development Policy Committee (NTDPC) was established by the Cabinet Secretariat as a high level committee chaired by Dr Rakesh Mohan, to assess the transport requirements of India's rapidly growing economy over the next two decades and recommend a comprehensive policy framework and actionable strategy to meet those needs effectively and efficiently.

In order to marshal the requisite information and undertake the substantive analyses NTDPC constituted a number of Working Groups, each focusing on a specific mode of transportation such as rail, or identified areas that merited priority attention, such as the movement of bulk commodities that retains a major role in India's transportation system. Services related to fuel supplies for producing energy as well as steel are particularly important to the economy. Moreover India's evolving economic geography and structural changes in the energy system, such as the increasing role of natural gas and growing imports of coal, will impose new demands on the transport network that require careful planning. Accordingly, the Working Group on an Integrated Strategy for Bulk Transport of Energy and Related Commodities in India, was set up under the chairmanship of Mr. P. Uma Shankar, Secretary, Ministry of Power, with Dr. Anupam Khanna, Principal Adviser, NTDPC[1] as Convener and comprising representatives from all the relevant ministries or departments as well as some members from the private sector.

The Working Group was charged with developing final demand scenarios over a 20-year horizon (until 2031-32), and estimating the railway, road, pipeline, and port capacities along with associated requirements for capital investments and operating costs in order to deliver energy in usable form to meet the demand in the most economic and strategically robust manner. The Working Group made maximum use of the data and information already available but tested it rigorously for consistency. Rather than reinvent the wheel, it built upon the analyses already underway for preparing the 12th Five-Year Plan.

In order to keep the process manageable, five sub-groups were constituted to focus on specific issues as follows: (1) Demand Scenarios for Electricity (chaired by Mr. Major Singh, Central Electricity Authority (CEA)); (2) Location of Energy and Fuel Production Facilities and Transfer Facilities (Ms. Neerja Mathur, CEA); (3) Optimization of Fuel and Electricity Delivery System Networks (Mr. Ranjan Jain (Railway Board)); (4) Oil & Gas Pipelines and Terminals (Mr. Apurva Chandra (Ministry of Petroleum and Natural Gas)); and (5) Material Transport Requirements of the Iron and Steel Industry (Mr. Udai Pratap Singh, (Ministry of Steel)). In each sub-group, the membership comprised technical experts co-opted from relevant government departments as well as private industry and consultant firms. Coordination between the subgroups was provided by the NTDPC Secretariat under the overall direction of the Working Group Chairman.

[1] Anupam Khanna left NTDPC in October 2011 to join NASSCOM but continued to work as Convenor of the Working Group.

Reports from the sub-groups formed the major part of the inputs for the analyses of the transport requirements for bulk transport. A comprehensive yet tractable analytical framework was critical for reaching coherent conclusions not only regarding the most efficient mode of transporting fuel (by rail, road or pipeline) but also the options regarding location and technology of power plants, mines and ports as well as the choice between transporting fuel versus transmitting electricity. The Working Group is grateful to ICF International for sharing key data and allowing the use of their proprietary India-Integrated Planning Model and providing initial analytical support on a *pro bono* basis. The assistance provided by ICF personnel, in particular: Amit Sharma; Ankush Sharma; Yasir Altaf; and Rashika Gupta is deeply appreciated. We are also grateful to the Association of Power Producers (APP) for providing financial support for supplementary analysis by ICF International. The contribution of RITES Ltd. in providing maps and congestion data on rail routes is also appreciated.

The Working Group held three formal meetings on: 17th June, 2011; 11th July, 2011; and 16th November, 2011. The preparation of the report and the associated analyses were undertaken at the NTDPC Secretariat by Daljit Singh and Dr. Anupam Khanna with able assistance from Geeta Garg. The maps in the report help illuminate essential points and were developed by Rishab Sethi, also at the Secretariat.

Inputs were also solicited from various ministries and government agencies and individual members of the sub-groups through in-person or telephonic interviews. In particular, the team benefited greatly from interactions with: D.N. Prasad from the Ministry of Coal; Janardhana Rao and Iftikar Ahmed of Indian Ports Association; Ramesh Kumar and P. Jindal of the Central Electricity Authority; Suchitra Sengupta and S.K. Saluja of the Economic Research Unit of the Joint Plant Committee, Ministry of Steel; Archana Mathur, Ashutosh Sharma and Sukhveer Singh of the Ministry of Petroleum and Natural Gas; Sushant K. Mishra, Devendra Singh and Rinkesh Roy of the Ministry of Railways; T. Gouricharan of the Central Institute of Mining and Fuel Research (CIMFR); V.K. Agrawal and Awadhesh Mani of the National Load Dispatch Centre; M.M. Hasija of the Ministry of Shipping; and Nilanjana Roy and G. Ramakanth of the Coal Controller’s Organization, Ministry of Coal.

List of Abbreviations

AGCL	Assam Gas Company Limited
ATF	Aviation Turbine Fuel
AP	Andhra Pradesh
BAU	Business As Usual
BCCL	Bharat Coking Coal Limited
Bcm	Billion Cubic Meters
BF-BOF	Blast Furnace- Basic Oxygen Furnace
Bt	Billion Tonnes
CAGR	Cumulative Average Growth Rate
CBM	Coal Bed Methane
CCL	Central Coalfields Limited
CEA	Central Electricity Authority
CIL	Coal India Limited
CMPDI	Central Mine Planning and Design Institute
CS	Crude Steel
CWET	Centre for Wind Energy Technology
DGH	Directorate General of Hydrocarbons
ECL	Eastern Coalfields Limited
FBC	Fluidized Bed Combustion
FSA	Fuel Supply Agreements
GAIL	Gas Authority of India Limited
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GSPC	Gujarat State Petroleum Corporation
GSPL	Gujarat State Petronet Limited
GW	Giga-watt = 1,000 MW
IEA	International Energy Agency
IEP	Integrated Energy Policy
IOCL	Indian Oil Corporation Ltd.
JNNSM	Jawaharlal Nehru National Solar Mission
km	Kilo meters
kWh	kilo Watt hour
LBNL	Lawrence Berkeley National Laboratory
MCL	Mahanadi Coalfields Limited
MMSCMD	Million Standard Cubic Meters per Day
MNRE	Ministry of New and Renewable Energy
MoC	Ministry of Coal
MoEF	Ministry of Environment and Forest
MoP	Ministry of Power
MoP&NG	Ministryof Petroleum and Natural Gas
MoS	Ministry of Steel
MP	Madhya Pradesh
Mt	Million Tonnes
Mtpa	Million tonnes per annum
NAPCC	National Action Plan on Climate Change
NCL	Northern Coalfields Limited
NTDPC	National Transport Development Policy Committee
OIL	Oil India Limited
ONGC	Oil and Natural Gas Corporation
OTS	Office of Transport Strategy
PAP	Project Affected People

PHBPL	Paradip- Haldia-Barauni Pipe Line
PMO	Prime Minister’s Office
PNGRB	Petroleum and Natural Gas Regulatory Board
POL	Petroleum, Oils & Lubricants
PPAC	Petroleum Planning and Analysis Cell
PSUs	Public Sector Undertakings
RGTIL	Reliance Gas Transport Infrastructure Limited
RITES	Rail India Technical and Economic Service
R&R	Resettlement and Rehabilitation
ROW	Right of Way
RPO	Renewable Portfolio Obligations
SECL	South- Eastern Coalfields Limited
SMPL	Salaya Mathura Pipe Line
TANGEDCO	Tamil Nadu Generation and Distribution Corporation Limited
TWh	Terawatt hours (= billion kWh or billion units)
WB	West Bengal
WCL	Western Coalfields Limited

Executive Summary

The surge in economic growth witnessed in recent years in India has strained the capacity of its transport system as well as energy supply, particularly electric power. The government's ambitious development targets and plans as well as popular discourse attest to the importance of addressing such binding infrastructure constraints in a decisive manner over the next couple of decades in order to sustain high levels of economic growth and to make it more inclusive.

Movement of bulk commodities is a major role of India's transportation system. Coal accounts for almost half the freight volume on Indian Railways, which is a major supplier of transport services to the electric power and steel industries. The future poses profound challenges. Even if ambitious aims to improve energy intensity of the Indian economy are achieved, sustaining economic growth at 8-10 percent *per annum* over the next two decades will require massive increases in power generation and transportation of bulk commodities such as coal, iron and steel.

In this context, the National Transport Development Policy Committee (NTDPC) decided to constitute a Working Group on Integrated Strategy for Bulk Transport of Energy and Related Commodities in India, chaired by the Secretary, Ministry of Power and comprising representatives from all the relevant ministries and departments as well as some members from the private sector.

The Working Group was charged with developing final demand scenarios over a 20-year horizon (until 2031-32), and estimating the railway, road, pipeline, and port capacities along with associated requirements for capital investments and operating costs in order to deliver energy in usable form to meet the demand in the most economic and strategically robust manner. The Working Group made full use of the data and information already available but tested it rigorously for consistency. Rather than reinvent the wheel, it built upon the analyses already underway for preparing the 12th Five-Year Plan.

The work done on the transport requirements for bulk commodities is briefly described in the following sections. Pulling together these assessments of transport requirements, the Working Group's conclusions and recommendations provide estimates of the infrastructure requirements and associated investments for railways and ports to move the required amount of coal, iron ore and other bulk materials.

Location of Production and Supply Sources

Coal, oil, and natural gas are the three primary commercial energy sources, with coal being by far the largest source of energy in India. The bulk of the coal reserves are in three states – Odisha, Jharkhand and Chhattisgarh – which together have about 70 percent of the country's reserves of coal. Coal also comes from mines in Andhra Pradesh, Madhya Pradesh, Maharashtra, West Bengal and a small amount from Bihar. Thus domestic coal needs to be moved from the east to the rest of the country. The deficit between the country's demand for coal and domestic production is met by imports. Thermal (non-coking) coal is imported mainly from Indonesia (~70 percent) and South Africa (~20 percent) and it comes to various ports distributed along the eastern and western coasts. In contrast, coking coal which is imported mainly from Australia (~80 percent) comes mainly to four ports on the east coast which are near the iron-ore and steel production facilities – Paradip, Kolkata, Vishakhapatnam and Krishnapatnam.

Natural gas comes mostly (~85 percent) from off-shore wells in about equal amounts from the Eastern and Western side. The remaining 15 percent comes from on-shore wells in various states. India imports over 70 percent of its crude oil and this level is expected to increase as the economy grows. About 45 percent of the domestic crude oil production comes from on-shore wells distributed across several states, and the remaining 55 percent comes from off-shore wells.

Coal is the dominant fuel in the electricity generation capacity mix of the country firing about two thirds of the country's capacity, and providing about 70 percent of the electrical energy. Coal fired capacity is distributed across the country except for the Northeastern region, with the Western region being the biggest contributor. Currently, the Northern region, including the hilly regions of HP, J&K, Uttarakhand and Punjab has the most hydro capacity followed closely by the Southern region. The contribution of the North-Eastern region is miniscule currently, but is expected to grow as more of its very large hydro potential is realized.

Plausible Demand Scenarios for Electricity

The study used a set of three scenarios that provided reasonable estimates of potential upper and lower bounds on demand that would be meaningful for evaluating infrastructure requirements. The base case was based on the forecast in the Draft Electric Power Survey of India (EPS). The high demand scenario (aspiration case) was based on the assumption that India would achieve an income level of a middle income country by 2020 and a high middle income country by 2030. The low case assumed that energy delivery would not be able to keep up with the requirements for 8-9 percent growth and growth would grind down to an average of about 6 percent per year. Table ES-1 provides the national aggregate demand forecast for the three scenarios.

Table ES-1 National Annual Aggregate Demand by Scenario (TWh)

Case	2016-17	2021-22	2026-27	2031-32
Base	1516	2118	2938	3857
Low	1329	1736	2228	2808
Aspiration	1591	2422	3334	4603

Source: Working Group Research

Fuel Requirements for Power

Because domestic coal is the least expensive fuel for electricity, in each of the scenarios the entire amount of domestic coal available was used first, and hence the consumption of domestic coal in the scenarios was the same and was about 1,100 million tonnes (Mt) in 2031-32. Naturally, the amount of imported coal used was quite different in the three scenarios to account for the differences in the amount of electricity produced. Table ES-2 gives the projected consumption of imported coal by the power sector over the three scenarios.

Table ES-2 Total Consumption of Imported Coal by the Power Sector (Mt)

Case	2011-12	2016-17	2021-22	2026-27	2031-32
Base	73	88	138	266	355
Low	61	28	27	28	61
High	76	106	158	295	460

Transport Requirements for Petroleum and Natural Gas

Pipelines, because of their economic advantage, are the main mode of transport for petroleum and natural gas, although other modes are used to a limited extent. For example. private oil companies with refineries on the coast transport crude oil using coastal shipping. Some petroleum products are transported by rail, but even by 2031-32 (~105 million tonnes per annum (Mtpa)), the amounts are expected to be much smaller than the transport of coal, which is expected to be over 1,400 Mtpa. Expansion of pipeline capacity is being carried out. For natural gas, where transport requirements are expected to be about 790 million standard cubic meters per day (MMSCMD) by 2031-32, the pipeline capacity is expected to reach 1,175 MMSCMD by the end of the 13th Five Year Plan (2021-22). This indicates that the the pipeline network will be able to support the transport requirements for natural gas over the next 20 years. Thus, we see that the petroleum and natural gas sector is not expected to have much of an effect on the surface transport system.

However, this sector is going to have a huge impact on the requirements at ports. Total port traffic for petroleum, oils and lubricants (POL) is expected to reach 860 Mt by 2031-32. This volume is larger than the expected combined port traffic for thermal and coking coal (about 600 Mt).

Transport Requirements for the Iron and Steel Industry

The transport requirements of the steel industry are going to have a large impact on the transportation system for two reasons: (1) one tonne of steel requires 3-4 tonnes of raw materials; and (2) the intensity of steel use in the economy is expected to increase so the requirements for steel will grow faster than the GDP. The total quantity of material that will need to be transported for the steel industry is expected to reach 2200 Mt by 2031-32; a six-fold increase from 2011-12.

The main impact on the transport network is expected to come from the transport of iron ore and coking coal. Most of the major steel plants are located and are expected to continue to be located near iron ore mines. So while the amount of iron ore to be transported will be large, the distances will not be large and will use short rail routes. About 85 percent of the coking coal for the industry will be imported, and hence the requirements at ports will increase. Coking coal imports are expected to reach 240 Mtpa by 2031-32.

Conclusions and Recommendations

Economic growth is critically dependent on adequate amounts of electric power and steel. Almost all economic activity requires electricity, and steel is an important input for many industries. As we have seen, in order to sustain a GDP growth rate of 8 to 9 percent over the next two decades, India's requirements for bulk commodities are expected to grow rapidly.

These very large increases in the transport requirements for bulk commodities over the next two decades would be a challenge under any circumstances. For India the challenge is even bigger because our transport systems for bulk commodities are barely able to cope with the traffic today. The trunk railway network is heavily congested. Generally, a rail route is considered congested when the capacity utilization increases beyond 80 percent. Almost all the major rail routes over which coal and iron ore will be transported are operating above 100 percent of capacity. Build up of coal stocks at pit-heads is an early warning of the lack of capacity in the transport system to meet increased traffic.

Similarly, Indian ports are stretched to capacity. The capacity utilization averages 85 percent with at least four operating at a utilization level of 100 percent or more. International norms recommend that capacity utilization of ports be below 70 percent to avoid delays.

Unless well-planned steps to rapidly improve the bulk transport system are successfully implemented, the transport system will become a stranglehold on the economy starving it of energy materials and other key commodities that are essential for economic growth.

A. Rail Network

1. Critical Feeder Rail Routes at Mines. Eight critical feeder routes for coal are awaiting completion. Most of the additional coal that will be produced in the next two decades will come from the regions where these routes are located. Shortages of coal which are already slowing down the economy will become even more acute in the future if these feeder routes are not completed. Similarly, critical feeder routes for moving iron ore must be completed to ensure steel production keeps up with the economy's requirements. The total cost of these routes will be about Rs 3,500 crore for coal and Rs. 11,740 crore for iron ore; just 2.4 percent of the Railways budget for the 12th Five Year Plan, but with large benefits for the economy. These critical routes must be completed on the highest priority within the 12th Five Year Plan. Tables 6.4 and 6.5 in the report provide a list of these critical feeder routes.

2. Importance of Short Distance Transport of Coal. A progressively greater share of coal will be used within the coal producing states and coastal states, and it is expected that the share of short rail routes, road, merry-go-round (MGR) systems and conveyor belts or ropes will grow. Therefore, attention must be focused on these modes of transporting coal to ensure that the power sector does not suffer from insufficient supply of coal.

3. Feeder Routes to Power Plants within Coal Producing States. As in-state consumption of coal for power is likely to increase, much of this new capacity will come up in clusters of about 3,000-4,000 MW each. Roughly one feeder rail route to a cluster of power plants will be required every year in the tri-state region of Odisha, Jharkhand and Chattisgarh. Because each such feeder route will take a minimum of six years to complete, planning for these routes must be coordinated with investments being planned in the power sector, and decisions for the corresponding transport investment should be taken simultaneously.

4. Construction of Dedicated Freight Corridors (DFCs). The Eastern DFC is likely to carry an overwhelming share of the long distance coal traffic, with its share increasing from about half currently to about two-thirds by 2031-32. Excluding the Southern DFC which is not expected to carry much coal, the other DFCs have a much smaller and about equal share of the long distance coal traffic. Therefore, from the perspective of transport of bulk commodities, the Eastern DFC must be given the highest priority among the DFCs, and should be completed within the 12th Five Year Plan. The Western, East-West, North-South and East Coast DFCs should be completed by the end of the 13th Plan, and the Southern DFC can be completed by the end of the 15th Plan. For all the DFCs that have one termination point in the eastern resource-rich part of the country, construction must start from there because bulk traffic is the highest in those areas. Furthermore, some of the consumption within the coal producing states may use short sections of DFCs, so transport within coal producing states will also be facilitated.

5. Adaptive Planning and Coordination between Ministries. The volume of domestic coal transported increases quite dramatically over each of the two decades, particularly in the eastern part of the country. A counter-intuitive result is that under the low growth scenario for the power sector, the actual movement of domestic coal is larger putting even more pressure on the rail freight system. This is because as growth slows, domestic coal is not required to the same extent closer to the producing area and is available to be sent to areas further away, thus reducing imports of coal. This increases the burden on the rail transport system, unfortunately right when public resources are more constrained.

More generally, we see from this study that there can be great variation in both the amount of coal to be transported and the pattern of the movement, triggered by changes in the rate at which the economy is growing, greater use of renewables, increased availability of gas or higher energy efficiency. Given this uncertainty, it is important that planning for bulk transport of energy commodities be adaptive. A strategic bulk transport planning group should be established that monitors developments and potential developments in coal and other fuel markets, renewable energy technologies, and domestic fuel supply. In response to changing conditions it should periodically (say every five years) direct changes in the plans for transport of fuels so that adequate fuel supplies are available to power plants without delay and at low cost. The group should include all major stakeholders and representatives from power, railways, and natural gas sectors.

6. Modernization of Equipment. Freight transport in India is far less efficient than rail in other countries. There is a great need for upgrading and modernizing equipment, rolling stock and rail lines. As the Railways recognizes, trains must be heavier, longer and faster in order to maximize the use of existing infrastructure**.** Heavy haul technology should be used wherever possible and new lines should be designed for it. It increases the capacity of trains about four-fold so that a train per day that results in transport of about one Mtpa using current technology would result in transport of 4 Mtpa.

7. Bulk Transport Related Investment Required in the Rail Network. Suggested plan-wise investments are given in Table ES-3. These investments in the rail network have been prioritized on two characteristics: (1) level of impact of the investment; and (2) urgency of the route development. Total investment of about Rs 670,000 crore over the twenty-year period will be required. The investment is relatively higher in the 12th and 13th Plan when most of the major investments will be made.

Table ES-3 Suggested Plan-Wise Investment for Railways (Rs Crore) (2011-12 prices)

Category of Investment	12th Plan	13th Plan	14th Plan	15th Plan
Critical Feeder Routes - Coal	3,150			
Critical Feeder Routes - Iron and Steel	11,740			
Feeder Routes for Power Plant Clusters	1,500	1,500	1,500	1,500
Eastern DFC	45,975			
Western DFC	26,845	11,505		
E-W DFC	16,467	32,933		
East Coast DFC	9,142	18,283		
N-S DFC	18,250	36,500		
Southern DFC			11,275	11,275
Additional Augmentation		48,185	48,185	48,185
Rolling Stock and Terminals	44,138	66,300	74,850	80,550
TOTAL	177,207	215,206	135,810	141,510

Source: Working Group Research

B. Ports

By 2031-32, Indian ports will have to handle five times more thermal coal than today, 7.5 times more coking coal, and about 3.5 times more POL. Indian ports are barely able to handle current levels of imports and so handling these large increases in the future will be a big challenge. There are several reasons for the poor performance of Indian ports: (1) insufficient drafts; (2) low level of mechanization and inadequate cargo handling equipment; (3) inadequate navigational aids and facilities; (4) insufficient use of information technology; and (5) insufficient storage space.

1. Need for a Vision for the Ports Sector. Efforts are being made to improve the performance of ports; however, they are focused on improving the performance of individual ports while improvements need to be made on a system-wide basis. From the perspective of port requirements for bulk commodities, a vision needs to be developed for the ports sector and a national strategy developed based on it. One issue is the establishment of mega ports because they provide very significant economies of scale and most of the world's major economies have a few mega ports. India has none. Mega ports can accomodate larger ships resulting in a reduction of up to 40 percent of transport costs. A vision for the ports sector should consider issues such as: How many mega ports should there be in the country and where should they be located. What will be the roles of mega ports, major ports and non-major ports in such a framework? What role should coastal shipping play in the framework?

2. Selection of Sites for Mega Ports. An analysis of the expected port traffic from POL, thermal coal, and coking coal over the next two decades reveals that Gujarat is by far the state that has the most port traffic for all three commodities, and would clearly be a prime location for a mega port. On the east coast, three states have a large amount of traffic -Odisha, AP and Tamil Nadu, and are potential candidate states for mega ports. On the west coast, in addition to Gujarat, one or two more mega ports will be required. Maharashtra has the largest amount of port traffic on the west coast after Gujarat, and it may be appropriate to have a port on the Southern end of the Maharashtra coast that could also be used to serve Goa and Karnataka. Some of the existing ports that have a deep draft and could be developed to become mega ports are: Mundra (Gujarat); Gangavaram (Andhra Pradesh); Dhamra (Odisha); and Ennore[2] (Tamil Nadu).

However, selection of sites for locating mega ports will require extensive modeling and analysis. First, all types of port traffic including containers and other commodities needs to be included in the analysis. Second, detailed data are required on the cost of development of candidate ports, and then detailed modeling is required to examine the costs and benefits of various alternative selections from a short list of potential sites.

3. Investments in the Port Sector. Indicative estimates of the required plan-wise investments in the ports sector for handling coal and POL are given in Table ES-4. We estimate that an investment of about Rs 140,000 crore will be required over the twenty year period.

In summary, this report underlines the importance of making advance plans for investment in railways and ports in an integrated manner for the transport of bulk commodities for the energy sector and for the iron and steel industry. If these investments are not made in a timely manner it will not be possible to achieve the growth envisaged for the country in the next two decades.

[2] While Ennore has a draft of only 16 meters and the requirement for Cape Size vessels is 18 meters, the soil there consists of sand and soft to medium clay and silt. Therefore, dredging costs are expected to be low.

Table ES-4. Investment Required in Ports for Coal and POL

	2011-12	2016-17	2021-22	2026-27	2031-32
Traffic (Mt)					
Thermal Coal	48	88	138	266	356
Coking Coal	30	65	108	173	238
POL	334	490	596	725	816
Capacity (Mt)					
Thermal Coal	62	114	179	346	463
Coking Coal	39	85	140	225	309
POL	434	637	775	943	1,061
Incremental Capacity Reqd (Mt)					
Thermal Coal		52	65	166	117
Coking Coal		46	56	85	85
POL		203	138	168	118
Cost of Creating Capacity (Rs crore) (2011-12 prices)					
Thermal Coal		2,860	3,575	9,152	6,435
Coking Coal		2,503	3,075	4,648	4,648
POL		10,546	7,166	8,720	6,152
Total		15,908	13,815	22,520	17,234
Cost of Other Facilities		15,908	13,815	22,520	17,234
Total Investment required		31,816	27,630	45,040	34,468
Total Cumulative Investment 2012-2032 (Rs Crore)					1,38,954

Chapter 1. Introduction

The surge in economic growth witnessed in recent years in India has strained the capacity of its transport system as well as energy supply, particularly electric power. The government's ambitious development targets and plans as well as popular discourse attest to the importance of addressing such binding infrastructure constraints in a decisive manner over the next couple of decades in order to sustain high levels of economic growth and to make it more inclusive.

Movement of bulk commodities is a major role of India's transportation system. For example, coal accounts for almost half the freight volume on Indian Railways which is a major supplier of transport services to the electric power and steel industries. Indeed, the congestion caused by inadequate expansion in transport capacity to date, especially on crucial links and corridors underlies many issues such as security of supply chains, inventory of raw materials, port-handling, etc. affecting industry.

The future poses more profound challenges. Even if ambitious aims to improve energy intensity of the Indian economy are achieved, sustaining economic growth at 8-10 percent *per annum* over the next two decades will require massive increases in power generation and transportation of bulk commodities such as coal, iron and steel. The task ahead is rendered more difficult by the evolving economic geography and structural changes in the energy system, such as the increasing role of natural gas and growing imports of coal that will impose new demands on the transport networks. Current projections for coal imports in 2031-32 and LNG imports in 2029-30 for example, are 355 million tonnes (Mt) and 162 million standard cubic meters per day (MMSCMD) respectively.

Finally, there is increasing recognition of the adverse environmental impacts, including not just local pollution and damage to habitats and/or livelihood of vulnerable groups but also global climate change that need to be addressed in an economically efficient, equitable and effective manner.

Development plans from the key ministries of the government as well as initiatives and investment proposals from the private sector seek to address the issues alluded to above. However, the needs are vast and multifaceted, while resources are necessarily limited and more importantly the issues are intimately interrelated and the viability of solutions is interdependent both in terms of the nature of the investment (e.g. transport coal or transmit power) as well as the timing and duration of execution. Hence a piecemeal approach to planning could be severely suboptimal leading to colossal wastage of resources and lost time.

Task Definition

Keeping in view what is stated above, the National Transport Development Policy Committee (NTDPC) decided to constitute a Working Group on Integrated Strategy for Bulk Transport of Energy and Related Commodities in India, chaired by the Secretary, Ministry of Power and comprising representatives from all the relevant ministries/departments as well as some members from the private sector. Briefly summarized, the WG was charged with developing final consumption (demand) scenarios for electricity, natural gas as well as steel over a 20-year horizon covering the next four 5-year national plans until 2031-32 disaggregated both by geographical location; identifying all existing and potential future locations for energy production facilities including electric power generating plants (separating thermal, hydroelectric, and nuclear), coal mines (differentiated to the extent possible by attributes of coal quality such as calorific value and ash content), natural gas production (onshore and offshore), and steel plants; characterizing existing capacities, expansion possibilities and new locations for ports and terminals for coal and Liquefied Natural Gas (LNG) imports and landing sites for offshore gas; and mapping currently existing transport links and future options (railway lines, road corridors, coastal shipping routes, inland waterways (if any), pipelines and transmission networks) to move energy in bulk over long distances either embodied in fuel commodities (coal, hydrocarbons) or disembodied electricity by wire.

The Working Group was charged with analyzing the data gathered in a comprehensive yet coherent and tractable framework to address the economic decisions relating to bulk transport of energy within India in an integrated manner. The choices necessarily include not only the most efficient mode of transporting fuel (by rail, road or pipeline) but also the location and technology of power generation and the choice between transporting fuel versus transmitting electricity. Moreover, achieving overall economic efficiency from a national perspective also requires optimizing the fuel "linkage" based on transport distances, choice of technology and other economic and environmentally significant variables such as calorific values, ash and sulfur content, carbon dioxide emissions, for example, of the coal utilized. The results of the analysis were to yield estimates of railway, road, pipeline, port and terminal capacities together with associated requirements for capital investments and operating costs in order to deliver energy in usable form to the final consumers. The WG was also tasked to take into account major constraints imposed by physical and environmental limitations and maintain maximum realism in terms of the time duration for executing and commissioning capital investments. Finally, cognizant of the role of current policies, regulatory frameworks and institutional structures, the task would not be complete without identifying requisite reforms necessary to achieve efficiency, equity and sustainability objectives.

Work Plan

The approach adopted to execute the mandate pays due regard to the complex system involving many disparate actors in the energy system and the uncertainties inherent in a 20-year time horizon including the structural transformation underway in the Indian economy and society. It has sought to make maximum use of the data and information already available but testing it rigorously for consistency among different parts. Rather than reinvent the wheel, the WG has sought to build upon the analyses already underway especially in view of the preoccupation of all the Government departments in preparing the 12th Five-Year Plan which has the added benefit of providing a degree of coherence in bridging medium-term actions contemplated and the ambitious long-term vision for our nation. More specifically, the aim is to set robust long-term directions so the strategy can be adapted as events unfold as well as identify actions and decisions that need to be taken now.

In order to keep the process manageable, five sub-groups were constituted to focus on requisite technical expertise on specific tasks as follows:

– Plausible Scenarios for Final Electricity Consumption

– Locate Energy/Fuel Production and Transfer Facilities

– Energy Transport Networks for Optimal Matching of Supply with Demand

– Oil & Gas Pipelines and Terminal Facilities

– Material Transport Requirements for Steel Industry

In each case, the membership comprised technical experts co-opted from relevant government departments as well as private industry and consultant firms. Coordination between the subgroups, each of which is chaired by an official of a different government department has been provided by the NTDPC secretariat under the overall direction of the WG Chairman.

Overview of the Report

The results of the effort are described in the rest of the report. The first step in assessing transport requirements for bulk commodities is to identify the origins and destinations of the materials that have to be moved. Chapter 2 identifies the location of domestic energy and mineral resources, the sources of commodity imports, and the location of production facilities. Next we turn to the electric power industry which consumes 75-80 percent of the coal produced, one of the major bulk commodities that the transportation system must move. Chapter 3 looks at plausible demand scenarios for electricity. Chapter 4 describes the modeling effort to identify likely location of power plants taking into consideration location of resources, transportation costs, and other constraints so that the cost to the nation is minimized. The results of the modeling effort provide estimates of where and how much of the fuels (mostly coal) will be required. Chapter 5 looks at the transport requirements of the petroleum, natural gas and steel industries. Pulling together information from the other chapters, Chapters 6 and 7 estimate the infrastructure requirements for railways and ports respectively to move the required amount of coal, iron ore and other bulk materials. The two chapters also discuss critical areas that need to attention so that the transportation system is able to meet the growing energy and other bulk material needs of the country, and does not become a bottleneck in the economic progress of the country. Finally, Chapter 8 gives our conclusions and recommendations.

Chapter 2. Production & Supply

Introduction

As a first step in assessing the transport requirements for bulk commodities, we identify the origins and destinations of the materials that have to be moved. Raw materials need to be moved from mines to production facilities, and finished products need to be moved from production facilities to the places they are used or consumed. In this chapter we identify the location of domestic energy and mineral resources, the sources of commodity imports, and the location of production facilities. We also describe the current and projected transfer facilities. For some materials such as coal where domestic demand will outstrip domestic supply, imports will make up the deficit. Therefore, we also describe briefly the geostrategic considerations that are likely to affect the import of coal.

Coal, oil, and natural gas are the three primary commercial energy sources. Being the most abundant fossil fuel in India, coal is by far the largest source of energy and supplies about 50 percent of the country's commercial energy needs. About 35 percent of the energy needs are met by oil, with more than 80 percent of that oil being imported. While natural gas provides only about 10 percent of India's commercial energy needs, the consumption of natural gas has risen faster than any other fuel in the recent years.

In addition to the bulk transport needs of the energy sector, we also look at the needs of the steel industry. The most important raw materials for the steel industry are iron ore and coking coal. India is blessed with very significant amount of good quality iron ore resources. A significant amount was being exported until the recent ban by the Supreme Court on exports of iron ore. Much of the coking coal reserves in the country have high ash content rendering them unsuitable for steel-making, consequently, the steel industry relies heavily on imports of coking coal.

In the following three sections, we cover coal, natural gas and petroleum resources. Then we identify locations of electric power plants. After that we look at the steel industry and identify the location of iron ore resources and steel plants. We follow that with a brief description of India's ports. Last, we identify the sources of imports of coal and discuss briefly the geostrategic and economic considerations that influence the market for imported coal.

Coal

Exploration for coal in India is carried out in stages. During preliminary exploration, geological surveys are undertaken to identify potential coal-bearing areas. In the next stage there is regional or promotional exploration where widespread drilling is carried out to establish the broad framework of the deposits (MoC, 2011). Progressively more intensive exploration is carried out before mining actually begins. The estimates of coal resources are placed in three categories: proven, indicated and inferred with proven being the most detailed exploration of the three.

About 80 percent of the potential coal bearing area of 18,000 sq km has been covered by regional exploration. Based on these and subsequent more detailed explorations, India's total geological resource has been estimated to be about 286 billion tonnes (Bt) of coal. Of this 114 Bt is proven resource, while 137 Bt and 34 Bt fall in the indicated and inferred categories respectively. Only about 12 percent of the geological resource contains coking coal; the bulk is non-coking coal. Indian coal is classified into grades, A through G, based on its gross calorific value (GCV) with grade A coal having the highest GCV. The GCV for the various grades is given in Annex III. 2.1.

Location of Coal Reserves

Coal India Limited (CIL) is the major indigenous coal producer and has seven production subsidiaries and an eighth subsidiary (CMPDI) that provides technical support to the seven production subsidiaries. Singareni Colleries Co. Ltd, jointly owned by the Governments of India and Andhra Pradesh, is also into coal production and supply. Details are given in Annex III. 2.2.

Table 2.1 shows the major reserves of coal given in the country, and Figure 2.1 gives their geographical location. Together these coalfields have a geological resource of about 232 Bt, more than 80 percent of the national resource and almost all of it in the eastern part of the country. Figure 2.2 gives the state-wise share of coal reserves. The bulk of the reserves are in three states – Odisha, Jharkhand and Chhattisgarh -which together have about 70 percent[3] of the country's reserves of coal. However, it should be noted that much of this coal is of the poor quality (mostly grade F, and some D or E).

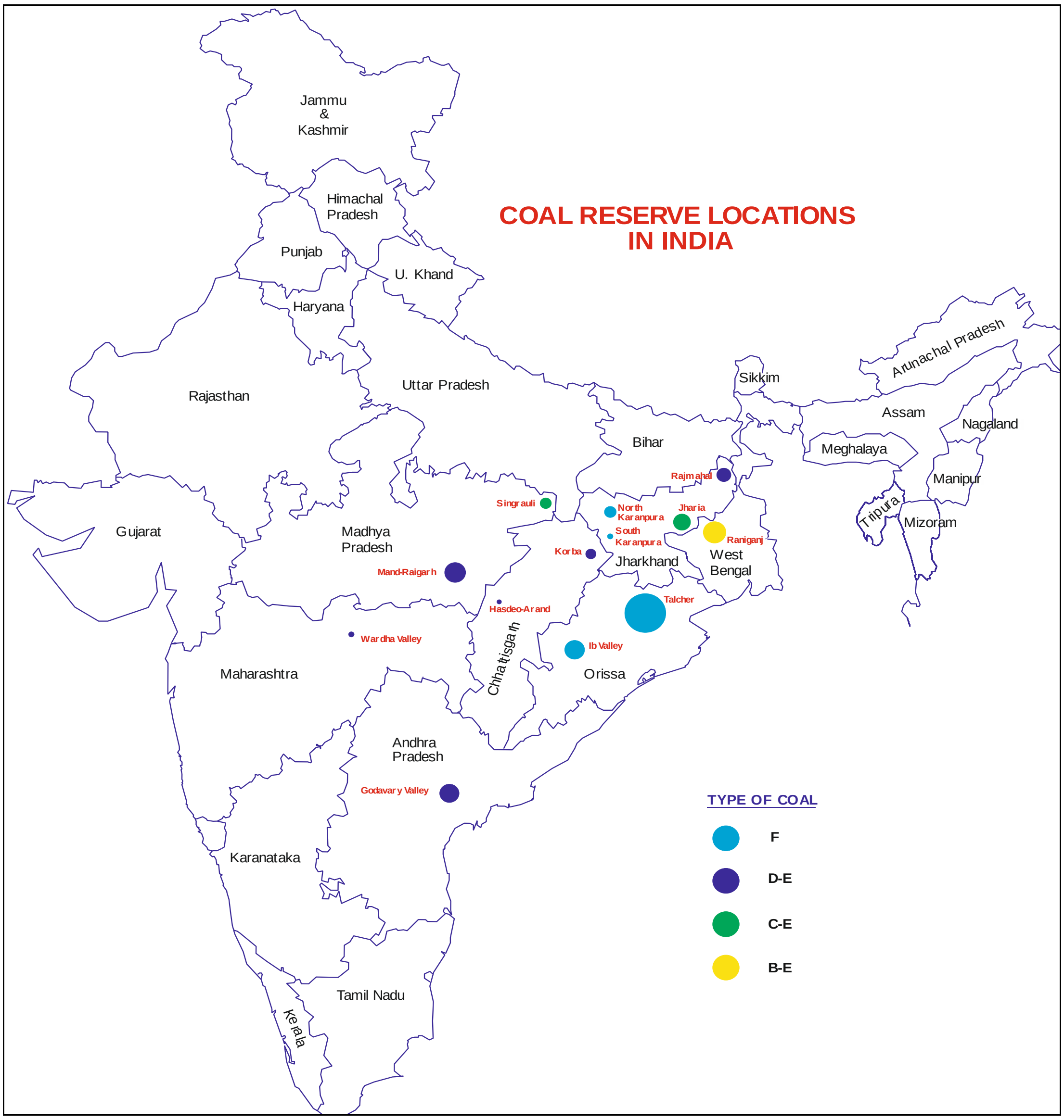
[3] These state-wise percentage shares are based on the total coal reserves in the country as given in Annex III.2.3. The shares may be somewhat different from those shown in Table 2.1 because Table 2.1 covers only the major coal reserves, about 80 percent of the total.

Table 2.1 Major Reserves of Coal

No.	Coalfield	State	Grade of Coal	Gross Geological Reserves (Bt)	Type of Coal
1	Talcher	Odisha	F	46.64	Thermal coal
2	Ib Valley	Odisha	F	22.52	- do -
3	North Karanpura	Jharkhand	F	13.35	- do -
4	South Karanpura	Jharkhand	F	6.30	- do -
5	Rajmahal	Jharkhand	D-E	16.20	- do -
6	Korba	Chhatisgarh	D-E	11.76	- do -
7	Hasdeo-Arand	Chhatisgarh	D-E	5.18	- do -
8	Mand-Raigarh	M.P	D-E	23.77	- do -
9	Singrauli	M.P	C-E	12.76	- do -
10	Wardha Valley	Maharashtra	D-E	6.26	- do -
11	Godavary Valley	A. P	D-E	22.05	- do -
12	Raniganj	W.B	B-E	25.83	thermal & semi coking
13	Jharia	Bihar	LVM , C – E	19.43	Coking
	TOTAL			232.05	
	Average ash content: 38-40 percent, Average heat rate 4,000 kcal/kg				

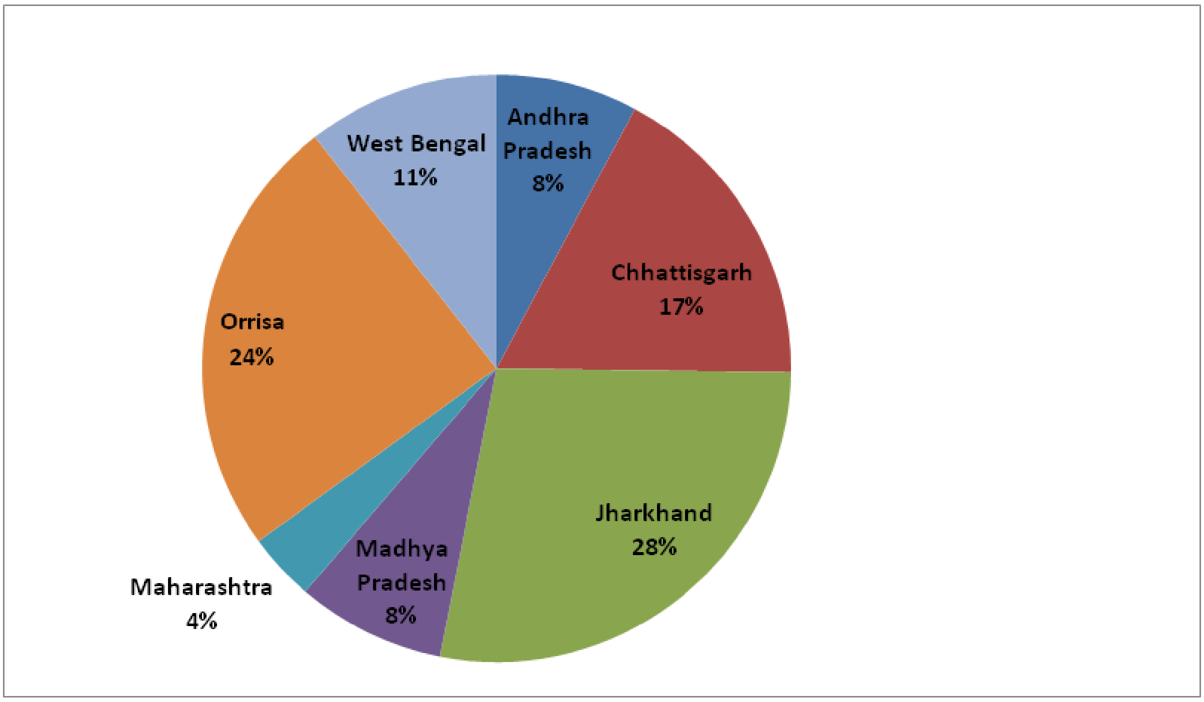
Source: Report of Sub Group 2

Figure 2.1 Location of Reserves of Coal



Source: Report of Sub Group 2

Figure 2.2 State-Wise Share of Coal Resources



Source: Report of Sub Group 2

Forecast of Production by Coal Companies

The tentative production capacity of CIL and other Companies is given in Table 2.2 below:

Table 2.2 Forecast of Production by Coal Companies (Mt)

Company	2011-12 (Est.)	2016-17	2021-22	2026-27	2031-32	Coal Fields
ECL	33	41	51	54	57	Rajmahal, Raniganj
BCCL	30	36	40	42	45	Jharia
CCL	51	83	110	117	124	North & South Karanpura
NCL	69	80	85	90	96	Singrauli
WCL	46	45	45	47	50	Wardha valley
SECL	112	140	182	193	205	Korba, Mand, Raigarh, Hasdeo Arand
MCL	106	140	195	207	219	Talcher, Ib valley
NEC	1	1	3	3	3	Assam
Total CIL	447	555	710	753	798	
SCCL	51	57	63	70	77	Godavary Valley
Captive	38	97	245	312	400	
Others	18	18	18	20	20	
All India	554	721	1,036	1,155	1,294	

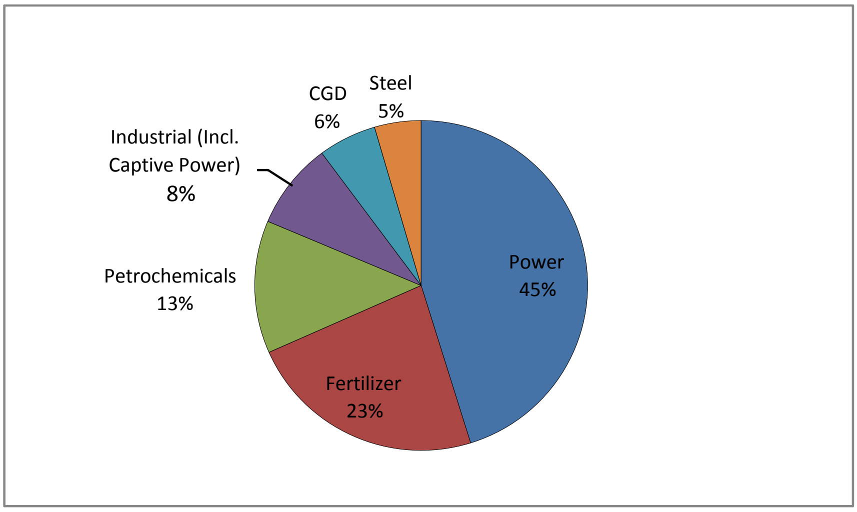
Source: Report of Sub Group 2

The average growth rate over the next twenty years for the amount of domestic coal that will be available works out to be 4.33 percent. However, the growth is higher (6.5 percent) during the first decade 2011-22 than the growth during the second decade 2022-32 (2.2 percent). As we shall see later, the overall growth rate over the two decades is considerably lower than the rate at which the demand for coal is expected to grow, necessitating increasing import of coal over the period.

Natural Gas

Interest in using natural gas as a fuel is growing because of its lower environmental impacts compared to coal and oil. It is increasingly being used in combined-cycle power stations because of the much higher efficiencies that are possible with advanced technology gas turbines. After the power sector, the next largest gas consumer of gas is the fertilizer sector. Gas is also used as a fuel in other Industries and in the commercial and domestic sector. Figure 2.3 shows the share of each sector to the total consumption of 177 MMSCMD in 2010-11.

Figure 2.3 Sector-Wise Gas Consumption 2010-11



Source: ICRA Rating Feature (2011).

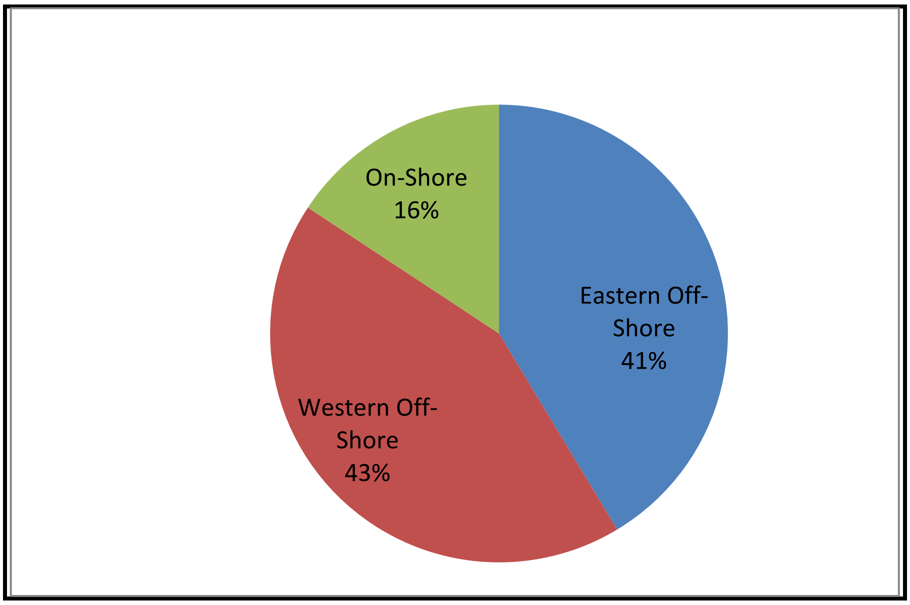
Exploration and production of natural gas has taken place in the sedimentary basins of the country. Table 2.3 gives the main gas fields for production of gas, and the production in 2010-11. As Figure 2.4 shows, the off-shore fields produce most of the domestic gas. With the recent decline in production from some of these fields such as from Reliance KG-D6 block, the contribution of off-shore production has decreased, but it still forms the bulk of domestic production.

Table 2.3 Production from Existing Gas Fields

Region	Location	Production (mcm)
Eastern Off-Shore	• Krishna-Godavari Basin (off the coast of AP). • North East Coast Basin (off the coast of West Bengal). • Cauvery Basin (off the coast of Tamil Nadu).	22,223
Western Off-Shore	• Cambay Basin (off the coast of Gujarat). • Mumbai Offshore Basin (off the coast of Maharashtra).	21,422
On-Shore	Andhra Pradesh	1,384
	Assam	2,729
	Gujarat	2,261
	Tamil Nadu	1,119
	Tripura	610
	West Bengal	41
TOTAL		51,789

***Source: Ministry of Petroleum & Natural Gas,* (2012).**

Figure 2.4 Geographical Share of Gas Production 2010-11



***Source: Ministry of Petroleum & Natural Gas,* (2012).**

Table 2.4 lists the gas fields being proposed for production in the next two decades. No new gas fields are proposed for the 15th Plan.

Table 2.4 Additional Gas Fields Being Proposed

Period	Eastern Off-Shore	Western Off-Shore	On-Shore
12th Plan	Mahanadi Basin (off Odisha coast)		
13th Plan		Andaman Off-shore (off coast of Andaman & Nicobar Islands)	• Gujarat (Shale Gas) • West Bengal (Shale Gas) • Tripura
14th Plan			• AP (Shale Gas) • Tamil Nadu (Shale Gas)

Source: Report of Sub Group 2

As Table 2.3 shows, domestic production of natural gas was 52 billion cubic meters (bcm) in 2010-11 corresponding to an average daily supply of about 140 MMSCMD. But consumption was 177 MMSCMD. The gap between consumption and domestic supply is met by imports of LNG. Currently, LNG re-gasification capacity in the country is 13.60 Mtpa (equivalent to 49 MMSCMD). Table 2.5 provides details and lists the additional LNG terminal capacity that is expected. It is expected that total gas availability including domestic production, LNG imports, and imports through trans-border pipelines will be about 360 MMSCMD by 2016-17 and 530 MMSCMD by 2021-22 (Report of Sub-Group 2).

Table 2.5 LNG Terminal and Regassification Capacity (Mtpa)

Terminal	Current Capacity	12th Plan	13th Plan
Dahej	10	15	15
HLPL Hazira	3.6	10	10
Dabhol		5	5
Kochi		5	10
Ennore		5	5
Mundra		5	10
East Coast		5	15
TOTAL	13.6	50	70

Source: Report of Sub Group 2

Shale Gas

Shale gas is an unconventional source of methane (the major component of natural gas) consisting of gas trapped in rock formations. New technology to extract the gas is transforming the energy outlook in the US, and now shale gas provides about a third of that country's gas supplies, and the price of gas has dropped dramatically.

Some of the on-shore sedimentary basins in India are reported to have organically rich shale, and India too has started looking into mapping of shale and generation of prospective sites. The strategy for development of shale gas consists of the following steps (MoP&NG, 2011):

1. Identification of promising basins. DGH has shortlisted the following six sedimentary basins for exploration:
   a. Cambay
   b. Krishna-Godavari
   c. Cauvery
   d. Assam
   e. Indo-Gangetic
   f. Damodar valley

2. Identification of areas within basins
3. Assessment of Resource
4. Formulation of shale gas policy

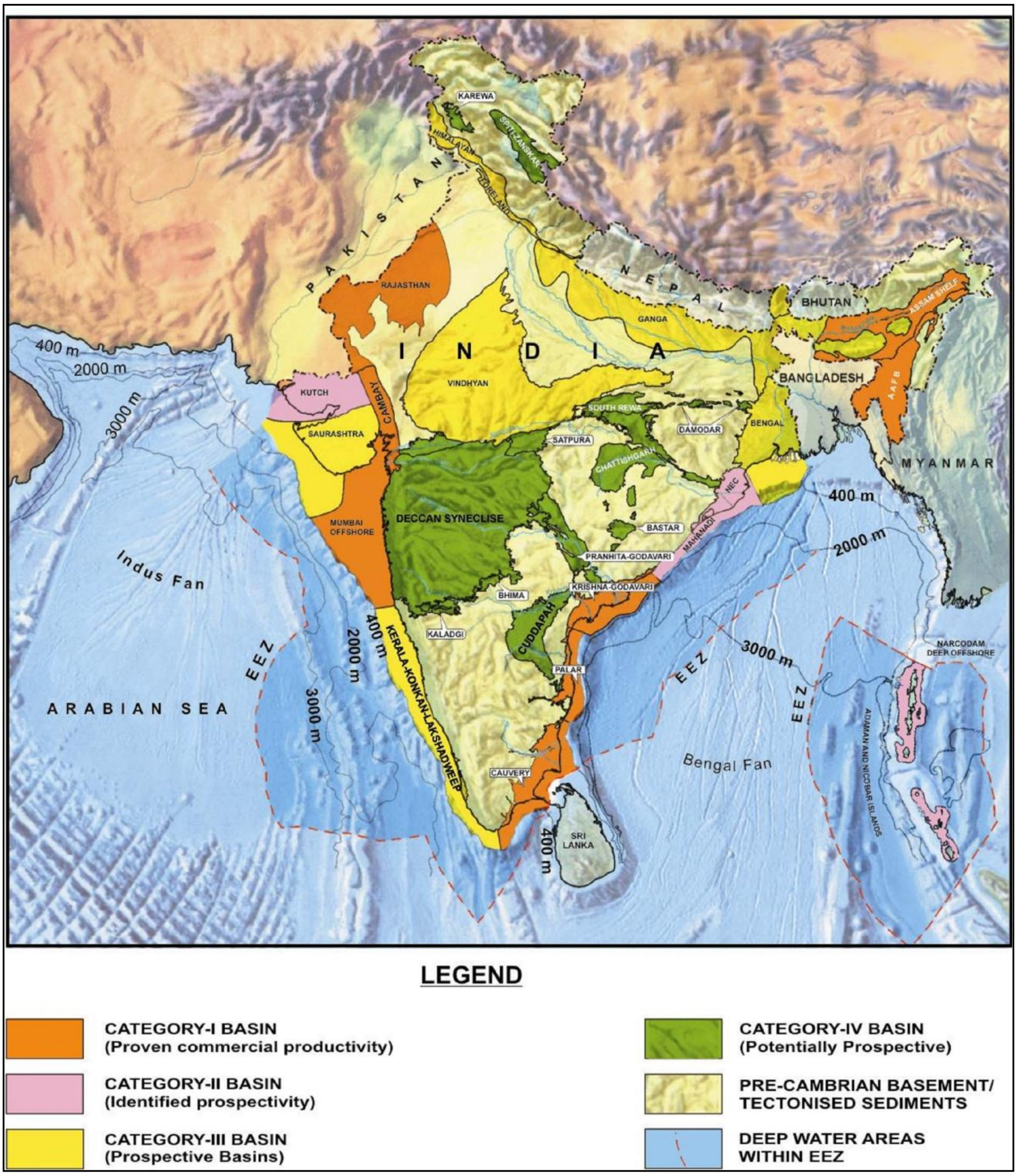
It should be noted however, that while *prima facie* shale gas may seem like a potential abundant and cheap fuel, it is likely to bring with it its own concerns about its use. There are serious environmental concerns associated with the production of shale gas related to water security, ground water pollution, and land subsidence. Therefore, its production and use may be severely restricted unless solutions are found to some of these environmental issues. If instead of increased gas availability, it is less than projected, then imports of coal would increase.

Petroleum, Oils and Lubricants (POL)

Even at the current low level of per capita consumption of energy, India imports over 70 percent of its crude oil requirements (mostly from the Middle-East and Iran). As the economy grows and per capita consumption increases, the level of imports will increase. In 2010-11, the country consumed 206 Mt of crude oil, of which 38 Mt were produced domestically and 164 Mt were imported (MoP&NG, 2011). In 2010-11, about 74 percent of the domestic production was by government owned companies (ONGC and OIL) and the rest by private companies or Joint Venture Companies.

Hydrocarbons (petroleum and natural gas) are found in sedimentary basins. Figure 2.5 gives a map showing the 26 sedimentary basins that have been identified. However, only the following seven basins have commercial production: Cambay, Assam Shelf, Mumbai Off-Shore, Krishna-Godavari, Cauvery, Assam Arakan and Rajasthan. In addition, the following three basins are known to have accumulation of hydrocarbons but there is no commercial production yet: Kutch, Mahanadi and Andaman-Nicobar.

Figure 2.5 Map of Sedimentary Basins in India



Source: Directorate General of Hydrocarbons (2012)

Table 2.6 gives the amount and location of current crude oil production from the seven sedimentary basins projected for 2010-11 (provisional). A little over half the production occurs off-shore, and the on-shore production is spread across several states.

Table 2.6 Production of Crude Oil ('000 tonnes)

Region/State		2010-11
ONSHORE	Gujarat	5,905
	Assam/ Nagaland	4,719
	Arunachal Pradesh	116
	Tamil Nadu	234
	Andhra Pradesh	305
	Rajasthan	5,149
	Total On-Shore	**16,428**
OFFSHORE	ONGC	17,002
	JVC/ Private	4,282
	Total Off-Shore	**21,284**
	Grand Total	**37,712**

Source: Ministry of Petroleum & Natural Gas (2012)

Refineries

As the demand for petroleum products has increased, the refining capacity has also increased either by the expansion of capacity at existing refineries or by setting up new refineries. As of June 2011, there were 21 refineries in the country out of which the bulk (17) are in the public sector. The total refining capacity is 193 Mtpa which is far higher than the domestic requirements, making India a net exporter of petroleum products (MoP&NG, 2013e). In 2010-11, India exported about 42 Mt of petroleum products (MoP&NG, 2011).

Annex III. 2.4 gives the location and capacity of the refineries in the country. Thirteen of them are in the coastal states while the others are spread out across the country.

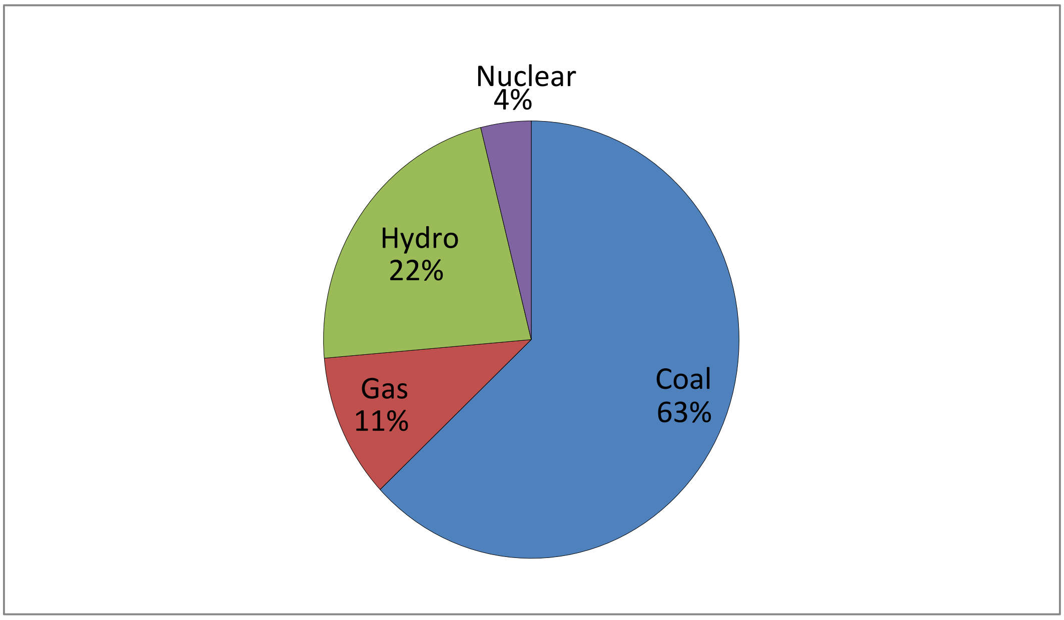
In this chapter we have discussed the location of resources. Much of the transportation of crude oil, petroleum products and natural gas is carried out by pipelines. Pipelines for these bulk products are covered in Chapter 5.

Power Plants

Location of Existing Conventional Generation

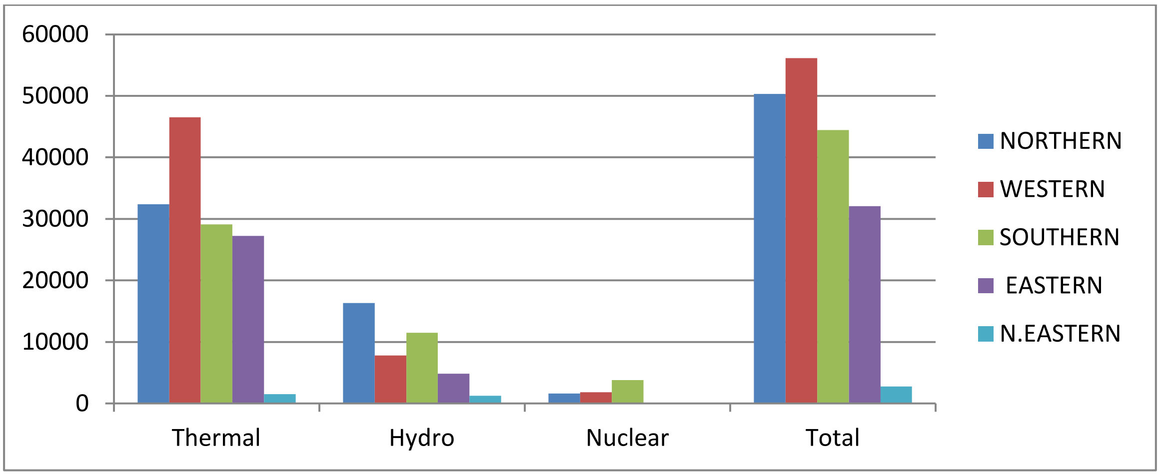
At the end of the 11th Plan, the generating capacity was about 175 GW excluding generation from renewable energy sources. As Figure 2.6 shows, coal is the dominant fuel in the capacity mix of the country firing about two thirds of the electricity generation capacity. Figure 2.7 below shows the contribution of the various regions to the overall power generation capacity. The Western Region is the largest contributor of thermal capacity (mostly coal) and total capacity. The contribution of the North-Eastern region is miniscule currently but is expected to grow as more of its very large hydro potential is realized. Currently, the Northern region which includes the hilly regions of HP, J&K, Uttarakhand and Punjab has the most hydro capacity followed closely by the Southern region. State-wise details of generating capacity are given in Annex III.2.5.

Figure 2.6 Generating Capacity Mix at End of Eleventh Plan



Source: Report of Sub Group 2

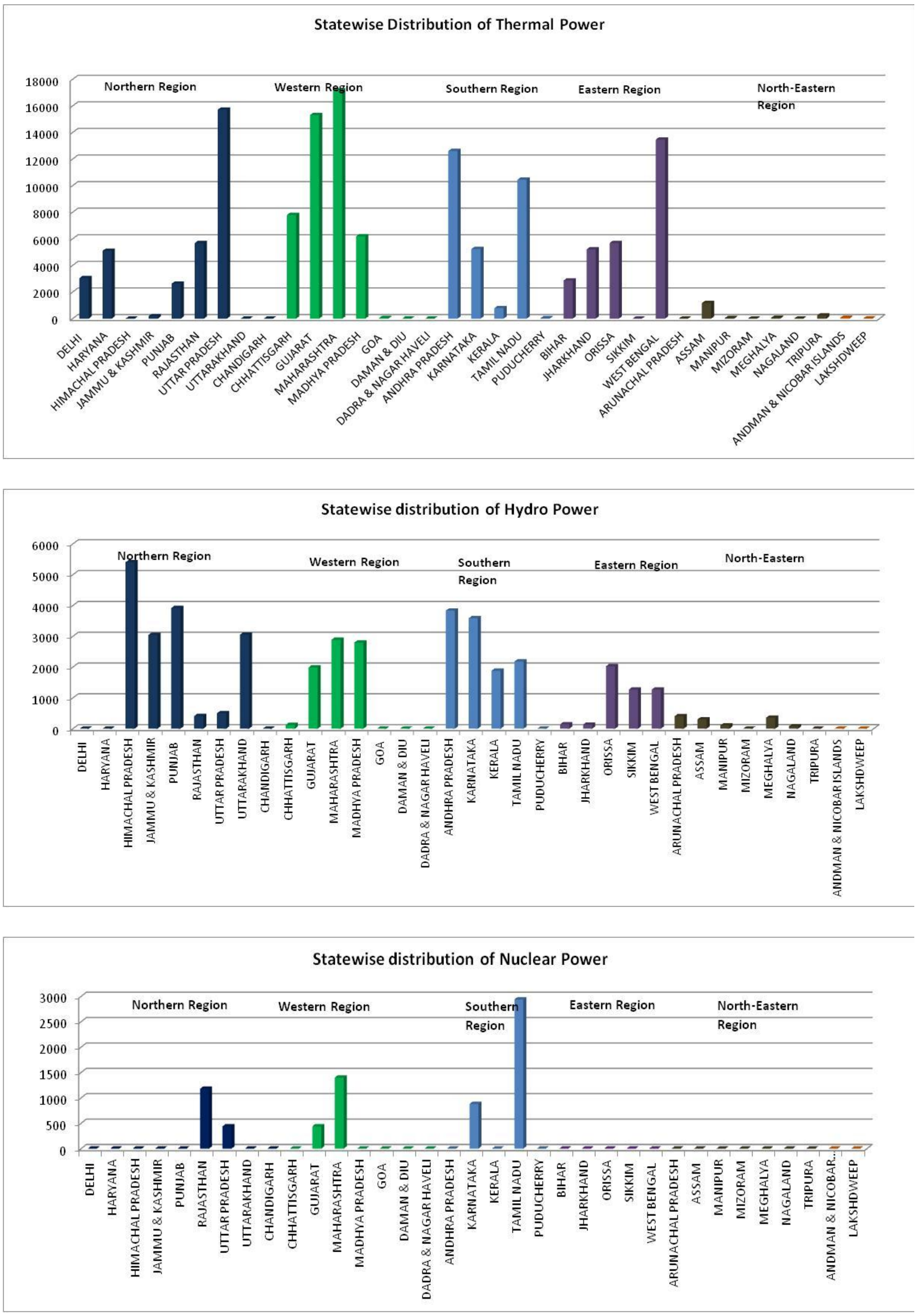
Figure 2.7 Regional Contribution to Generating Capacity



Source: Report of Sub Group 2

Figure 2.8 gives the state-wise contribution to capacity by type (thermal, hydro and nuclear). For thermal power, the big contributors are Uttar Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu and West Bengal. Together, these states provide more than 60 percent of the thermal power in the country. Himachal Pradesh stands out as the biggest contributor of hydro capacity

Figure 2.8 State-Wise Distribution of Power Plants by Type (MW)



Source: Report of Sub Group 2

Potential Locations for Future Power Plants

Sub-Group 2 identified potential locations for future power plants. From the shelf of coal, hydro and nuclear plants, based on the progress made in obtaining clearances and placing orders, it categorized the plants under the different five-year plans to arrive at a schedule of potential capacity additions as given in Table 2.7. State-wise details are given in Annex III.2.6.

Table 2.7 Potential Future Capacity Additions (MW)

Five-Year Plan	Hydro	Coal	Nuclear	Total
12th Plan	9,204	63,781	2,800	75,785
13th Plan	12,452	63,200	19,100	94,752
14th Plan	23,540	85,887	13,800	123,227
15th Plan	29,744	85,620	16,300	131,664
Total	74,940	298,488	52,000	425,428

Source: Report of Sub-Group 2

Factors Affecting Siting of Power Plants

There are several factors related to land, water availability, environmental impacts and public acceptability that constrain the amount of generation capacity that can be added in a particular state. These issues were considered in setting limits on state-wise capacity additions in the modeling exercise discussed in Chapter 4 to identify location of new power plants.

Land Acquisition

Land acquisition in recent times has become a critical issue for developers of plants for power and other key commodities such as steel. Land is increasingly becoming a scarce resource and availability of land is posing a serious challenge for future development of plants. Public anger in the process of land acquisition is leading either to delays or to abandonment of the infrastructure projects. Most of the concerns pertaining to land acquisition are:

- Reluctance on the part of the land owners to part with their land
- Inadequate amount of compensation vis-a-vis market prices.
- Unsatisfactory resettlement, rehabilitation and compensation for loss of livelihoods

Other issues that come in the way of land acquisition are mainly related to availability of land records, forest clearances and resettlement and rehabilitation (R&R) issues as listed below:

i) Lack of land records: The lack of updated land records is the most common problem that is encountered during land acquisition. The problem gets compounded due to low average holding per person and large number of claimants.

ii) Lack of clarity about the status of occupiers who are not owners.

iii) Right of way (ROW) for ash or water pipelines, coal conveyors and transmission lines

iv) MOEF clearance and acquisition of forest land coming in plant area and right of way (ROW).

v) Resettlement and rehabilitation of the project affected people (PAP) in general.

Potential Environmental Impacts

Power plants can have severe social and environmental impacts such as: air pollution; production of large quantities of ash; water pollution from ash ponds; and deposition of mercury. In addition, thermal power plants require large amounts of water, and geographic concentration can severely stress water resources in an area. Because of the economic attractiveness of certain areas as potential sites for power plants, there is a strong tendency for power plants to be geographically concentrated. This concentration, particularly in critically polluted areas can exacerbate the environmental impacts of thermal power plants. Hence before power projects are given clearances, studies to assess the regional carrying capacity need to be carried out to determine the amount of power generating capacity that the region can support.

Resistance from Local Communities to Power Plants

Many local communities have been protesting the construction of new power plants. Some recent examples are:

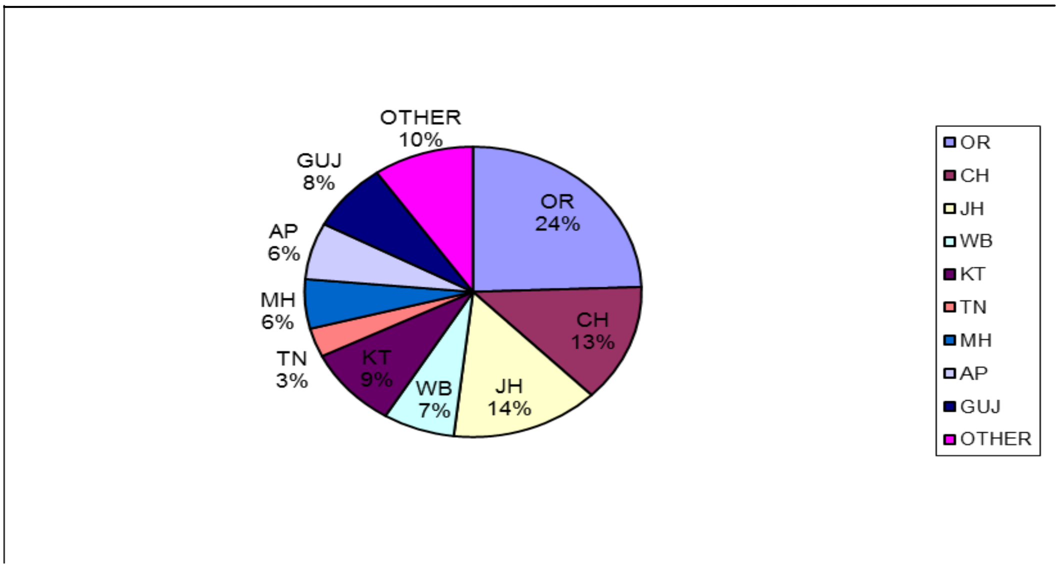
- Protest by farmers and fishermen against a 2460 MW power plant being constructed by Nagarjuna Construction Company in Srikakulam district, Andhra Pradesh, 2010.
- Protest against proposed Hanakon power plant in Karwar, Karnataka seen as a threat to biologically sensitive region, 2009.
- Protest by farmers against 3,600 MW KSK Mahanadi Power Project in Akaltara district of Chhattisgarh, 2011.
- Mango farmers' protest against seven thermal power plants in Ratnagiri district in Maharashtra, 2011.

Iron & Steel Plants

Steel capacity is located mostly near iron-ore mines in the mineral-rich states. As Figures 2.9 and 2.10 show Odisha, Jharkhand and Chattisgarh together have more than 50 percent of the steel capacity through most of the next two decades. In fact, there is a definite shift in investors' choice of location towards Odisha. Its share of steel capacity is expected to increase from 12 percent in 2010-11 to 25 percent by 2016-17 and remain at that level for the next two decades. In addition, there is a preference for large plants which currently constitute about 65 percent of the steel capacity. Interestingly, the share of large steel plants increases from 65 percent in 2010-11 to 76 percent in 2016-17 and is expected to remain at that level for the next two decades. These locational and size preferences are likely to continue because it is expected that BF-BOF (Blast Furnace – Basic Oxygen Furnace) technology and other hybrid technologies using hot metal will continue to predominate. Details are in Annex 2.7.

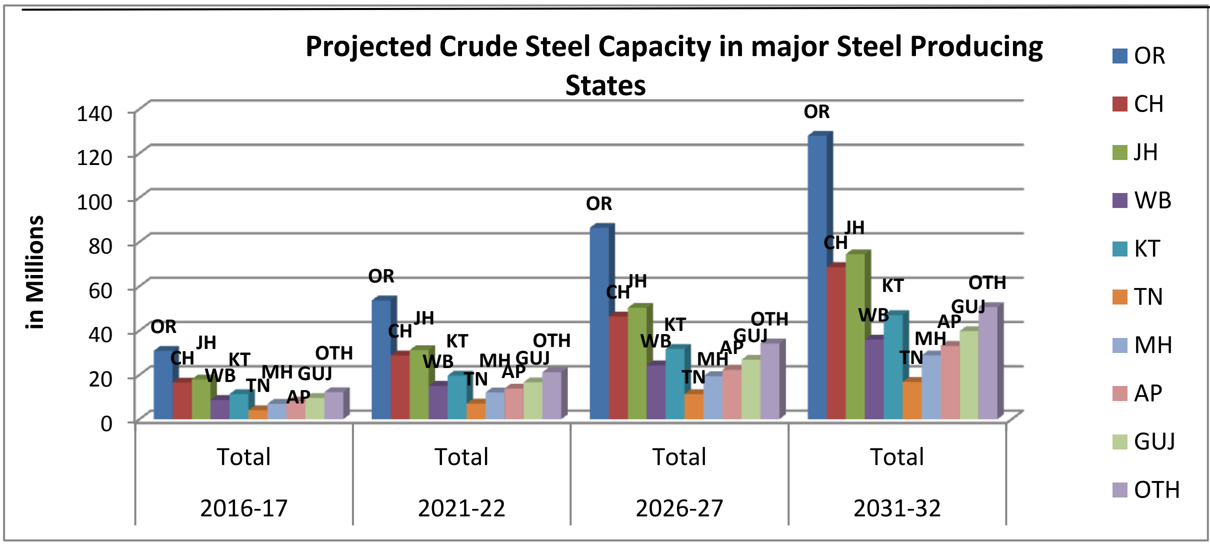
Small and medium units which now use about 70 percent sponge iron in the burden will gradually shift to using scrap as the country accumulates more scrap. When that happens, there will likely be a shift of steel capacity to the steel consuming areas. However, that is likely to happen only towards the end of the study period and is expected to be gradual.

Figure 2.9 State-Wise Share of Steel Capacity



Source: Ministry of Steel (2012a).

Figure 2.10 Projected Crude Steel Capacity in Major Steel Producing States



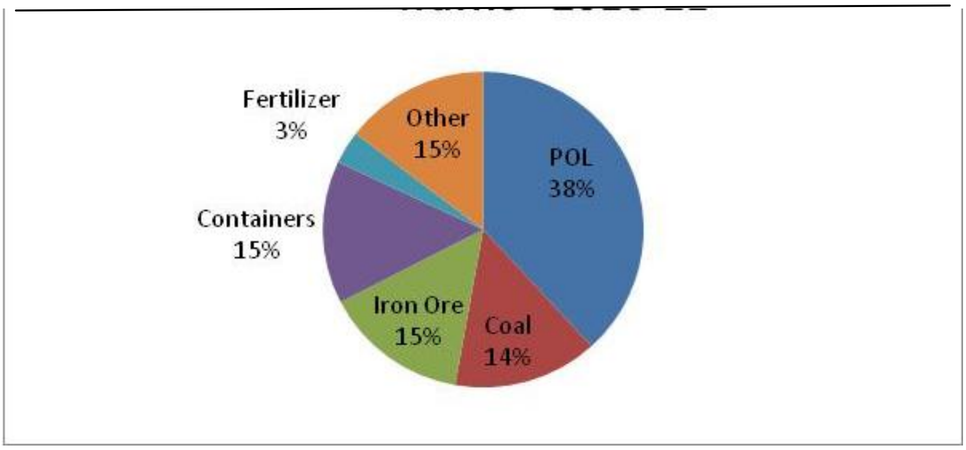
Source: Ministry of Steel (2012a).

Ports

Ports are an important component of the transport system for import and export of bulk commodities. They could also play a significant role in the movement of bulk commodities within the country through coastal shipping. However, that potential has been exploited to only to a very limited extent.

India has 13 major ports and 176 non-major ports. Major ports are ports that are administered by the Central government, while non-major ports are administered by the state governments. The total cargo handled by Indian ports has been growing at CAGR of almost 10 percent and in 2010-11 was 890 Mt. As Figure 2.11 shows, POL, coal and iron ore make up 67 percent of the cargo handled by Indian ports, with POL having the biggest share.

Figure 2.11 Commodity-Wise Break-Up of Port Traffic 2010-11



Source: Ministry of Shipping (2012)

Major Ports

There are thirteen major ports in India. They are evenly distributed along the coastline with seven on the eastern coast and six on the western coast. The traffic at major ports has increased over the last decade at about 7.4 percent, a bit slower than the overall port traffic implying a loss of share to non-major ports. Currently, major ports handle 570 Mt (2010-11) about 64 percent of the total port traffic. With major ports too, POL, coal and iron-ore make up a major part of the cargo handled; however, the share of the three together is 59 percent, about ten percentage points lower than the share in overall port traffic. The total capacity of major ports in 2011 was 670 Mt. With traffic being 570 Mt, this means a capacity utilization of about 85 percent. As we discuss later, this high utilization rate on average is an indicator of the shortage of capacity and consequent congestion at Indian ports.

In 2005, a Committee of Secretaries was set up to establish policies to improve port connectivity. The Committee recommended that each major port should be connected, at a minimum, by a four lane road and double line rail. Overall all major ports have reasonable road connectivity linking ports to the highways. On the issue of rail connectivity, Kolkata, Haldia, Vizag, Ennore, Chennai, Tuticorin have the required double line connectivity. For the other ports the provision of double line connectivity is in progress. More details are provided in Chapter 6.

Non-Major Ports

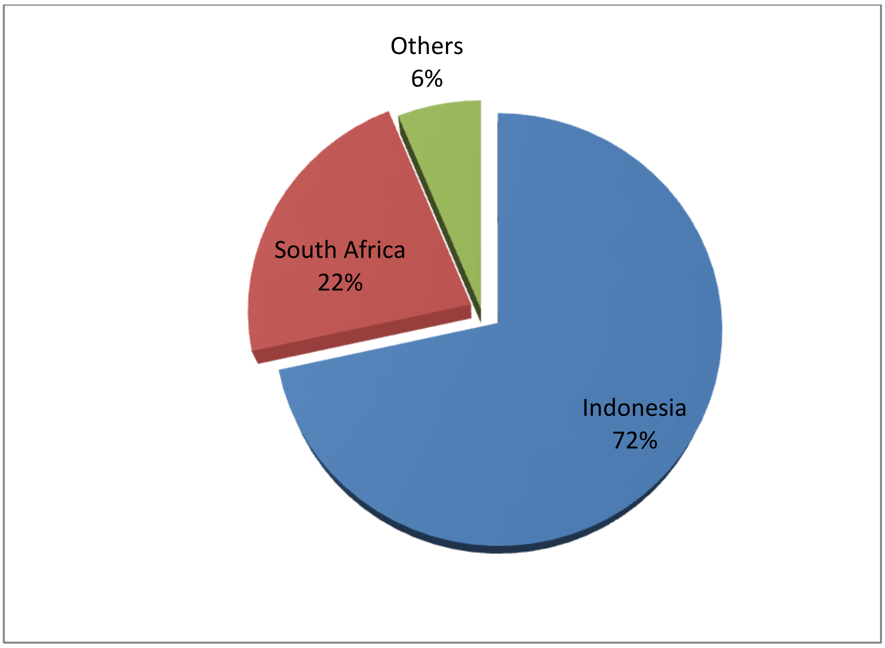
While there are 176 non-major ports spread across the coastline of India, only 61 of them handle cargo traffic, the rest are mainly fishing harbours. Even out of the 61, only six have rail connectivity up to the port. Another 8-10 have a railway station nearby, but need last-mile connectivity. In spite of these limitations, the share of traffic of non-major ports has increased from 11 percent to 36 percent in the last decade. This growth has been led mostly by the non-major ports in Gujarat – Sikka, Mundra, Hazira and Pipavav. The non-major ports have been able to attract private investment because they are seen as more business-oriented, customer friendly, inexpensive and more efficient. POL has the largest share of non-major port traffic at almost 50 percent, followed by coal at 18.6 percent and iron-ore at 13.5 percent.

Import of Coal

As discussed earlier, imported coal will bridge the deficit between the demand for coal and domestic supply. In the case of thermal coal, this deficit is likely to increase because production of domestic coal will increase at a slower rate than demand. In the case of coking coal, there is limited availability of it in India and we are already importing a large fraction of the country's requirements. Because the production of steel is expected to increase rapidly, the import of coking coal is also expected to grow rapidly. Imported coal is of considerably better quality than domestic coal. While most of the domestic coal has a gross calorific value (GCV) in the range of 3600-4200 kcal/kg, imported coal has a GCV in the range 5200-6500 kcal/kg with Australian coal being at the higher end of the range, Indonesian coal at the lower end of the range, and South African coal being in the middle of the range. Therefore, less imported coal is required than domestic coal for producing the same amount of electricity. A reasonable approximation is that one tonne of imported coal is equivalent to 1.5 tonnes of domestic coal.

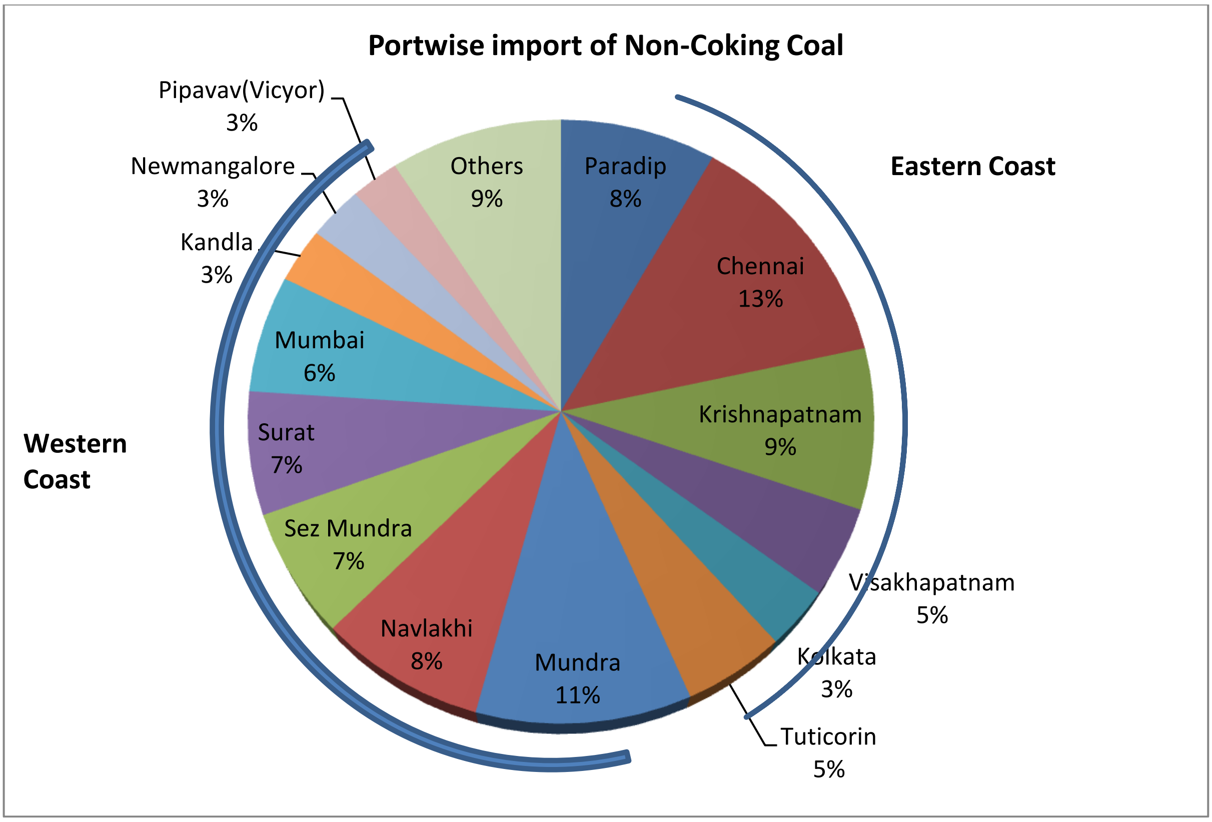
Using the data for FY 2010-11 to illustrate the pattern of India's coal imports, we see from Figure 2.13 that almost all the imported non-coking coal comes from Indonesia and South Africa with Indonesia being by far the biggest supplier (72 percent). Figure 2.14 shows that these imports of non-coking coal are roughly evenly distributed between destination ports on the east and west coasts. On the east coast with Chennai, Krishnapatnam and Paradip have the biggest share. Vizag, Kolkata and Tuticorin have a smaller yet significant share. On the west coast Mundra has the largest share, followed by SEZ Mundra, Navalakhi, Surat and Mumbia. Kandla, New Mangalore and Pipav also get some imports of non-coking coal.

Figure 2.13 Import of Non-Coking Coal by Source Country (2010-11)



Source: Coal Controller's Organization (2012a)

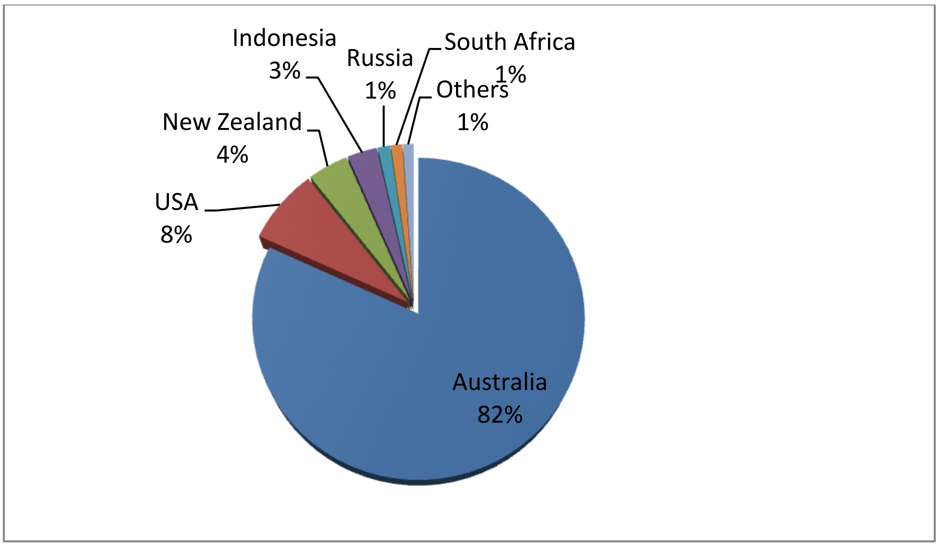
Figure 2.14 Destination Port-Wise Non-Coking Coal Imports (2010-11)



Source: Coal Controller's Organization (2012a)

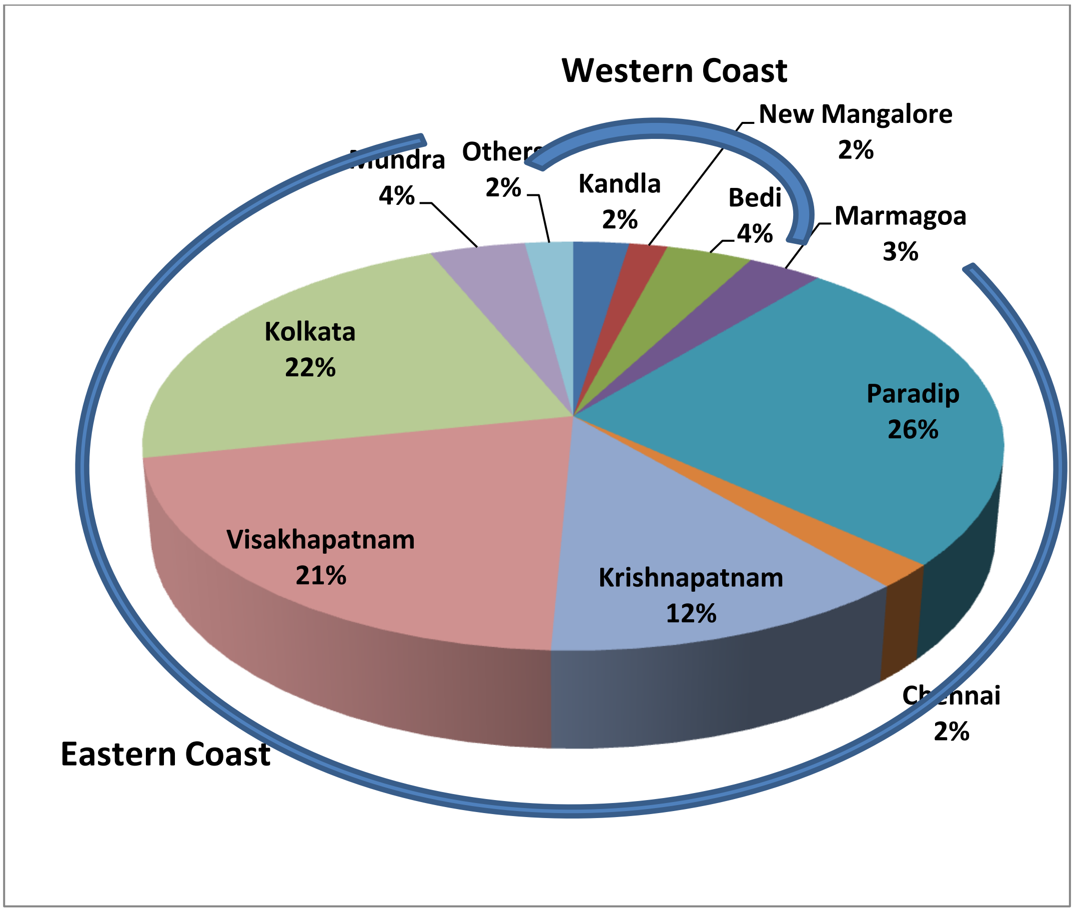
Figures 2.15 and 2.16 show the pattern of imports for coking coal. In this case, Australia is clearly the predominant supplier (80 percent) of coking coal. Relatively smaller amounts are also sourced from USA, New Zealand, Indonesia and South Africa. About 80 percent of the coking coal goes to four ports on the east coast –Paradip, Kolkata, Vishakhapatnam and Krishnapatnam which are near the areas where most of the large steel plants are located.

Figure 2.15 Import of Coking Coal by Country of Origin (2010-11)



Source: Coal Controller's Organization (2012a)

Figure 2.16 Destination Port-Wise Import of Coking Coal (2010-11)



Source: Coal Controller's Organization (2012a)

International Coal Market

In 2009, China and India's imports of non-coking coal constituted about 12.5 percent and 6.4 percent of the global market of 736 Mt. Going forward, with the imports by other countries remaining relatively steady, China and India are expected to account for about 90 percent of the growth in the global market (CLSA, 2010).

Because China's consumption of coal accounts for about half of the global consumption of coal, a relatively small mismatch between domestic supply and demand is likely to have a major effect on global markets for coal (IEA, 2011). China will be the driver of the global coal market. There are several uncertainties about whether Chinese domestic production will be able to meet the country's growing demand: (1) In addition to boosting production at existing coal mines, new coal mines will need to be developed; (2) Some of the new mines are very far from the major industrial cities posing transportation challenges for infrastructure that is already congested; and (3) As China intends to reduce the environmental impact associated with its coal consumption, significant investment will be required for upgrading power plants (IEA, 2011).

Most coal price forecasts expect prices for thermal coal to remain high and hover around $100 per tonne (in current dollars) for the next several years (CLSA, 2010; KPMG, 2012; WB, 2012).

Summary

The bulk of the coal reserves are in the three states – Odisha, Jharkhand and Chhattisgarh – which together have about 70 percent of the country's reserves of coal. Coal also comes from mines in AP, MP, Maharashtra, West Bengal and a small amount from Bihar. Thus domestic coal needs to be moved from the east to the rest of the country. The deficit between the country's demand for coal and domestic production is met by imports. Thermal (non-coking) coal is imported mainly from Indonesia (~70 percent) and South Africa (~20 percent) and it comes to various ports distributed along the eastern and western coasts. In contrast, coking coal which is imported mainly from Australia (~80 percent) comes mainly to four ports on the eastern coast which are near the iron-ore and steel production facilities – Paradip, Kolkata, Vishakhapatnam and Krishnapatnam.

Natural gas comes mostly (~85 percent) from off-shore wells in about equal amounts from the Eastern and Western side. The remaining 15 percent comes from on-shore wells in various states. India imports over 70 percent of its crude oil and this level is expected to increase as the economy grows. About 45 percent of the domestic crude oil production comes from on-shore wells distributed across several states, and the remaining 55 percent comes from off-shore wells.

Coal is the dominant fuel in the electricity generation capacity mix of the country firing about two thirds of the country's capacity, and providing about 70 percent of the electrical energy. Coal fired capacity is distributed across the country except for the Northeastern region, with the Western region being the biggest contributor. Currently, the Northern region, including the hilly regions of HP, J&K, Uttarkhand and Punjab has the most hydro capacity followed closely by the Southern region. The contribution of the North-Eastern region is miniscule currently, but is expected to grow as more of its very large hydro potential is realized.

Chapter 3. Plausible Demand Scenarios for Electricity

The Central Electricity Authority (CEA) produces electricity demand forecasts every five years under the Electric Power Survey of India (EPS). These forecasts are released to coincide with the national five-year plans.

Like previous editions of the EPS, the 18th EPS covers annual forecasts for the 12th five-year plan, 2012-2013 through 2016-2017 (CEA, 2012). It also contains forecasts for the terminal year of the 13th five-year plan (2021-2022) and 14th five-year plan (2026- 2027). A draft of the 18th EPS, containing interim results as available on September 2011, has been used for this analysis. Although the draft 18th EPS provides the outline till 2026-2027, for this analysis the outlook horizon in the draft provided was extended through to the terminal year of the 15th five-year plan, 2031-32.

EPS is one of the key electricity demand forecasts in the country. It is widely used across the industry and by the states and union territories as one of the most credible reference points. The forecasts are granular and provide detail by state /union territory, and by end-use category. It is developed using the partial end-use method, with inputs from the states and a wide range of stakeholders. The initial data feed is subjected to a high level of additional analysis and quality assurance before the EPS is released.

The objective of this exercise was to outline a broad set of demand scenarios that capture the potential range for demand which could then be used to identify the magnitude and location of generating capacity additions and subsequently to evaluate the fuel transport capacity to support such capacity addition. The study design for the electricity demand component has been approached accordingly. It seeks to provide a reasonable estimates of potential lower and upper bounds on demand that would be meaningful for evaluating transport infrastructure capability and is not intended to represent a specific demand forecast.

The base case is based on the EPS forecast. For the other scenarios, a top down scenario approach is used for this analysis, with two-tier scenario matrix. First, a high and low demand scenario is developed at the national level using CEA's draft 18th EPS as the baseline. Second, the high and low national demand estimates are parsed to the states using different regional growth scenarios. CEA's 18th EPS provides regional granularity.

The subsequent parts of the broader transport study intended to use only a few of the demand scenarios and the not the full matrix of possibilities. As a result, the second tier scenario development, the regional growth aspects were conducted only on the high demand scenario.

The scenarios provide a wide range across the impacts on transportation can be fully evaluated. Under the base case electricity demand grows by annual average growth of 6.4 percent between 2011-12 and 2031-2032; under the high electricity demand scenario that growth rate is 7.3 percent, while under the low demand growth scenario it is 5 percent. These correspond roughly to GDP growth rates of 8 percent for the base case, 9 percent for the high case, 6 percent for the low case.

Annex III.3.1 provides the state level projections under the three regional scenarios for each terminal year of the 5 year plan through 2031-2032.

The remainder of the section discusses the development of electricity demand and discusses the results.

Demand Scenarios

Base Case Electricity Demand

CEA's draft 18th EPS is used as the basis for the base case scenario. The EPS does not typically include captive generation and captures only utility level demand. However, for this analysis, the base case includes the draft 18th EPS adjusted to include captive generation. The base case in this scenario, thus, represents total electricity demand. Throughout this discussion, this analysis focuses only on energy demand. Peak demand is derived by retaining the same energy to peak ratio provided in the draft 18th EPS.

Around the base case scenario, two alternate high and low national-level demand scenarios were first developed. The high demand scenario is based on an aspirational per-capita electricity consumption goal. The low demand scenario is based on a low economic growth outlook and adjusts the electricity demand forecast presented in the Integrated Energy Policy (IEP). The approach and methodology for deriving the high and low electricity demand scenarios are described in greater detail below.

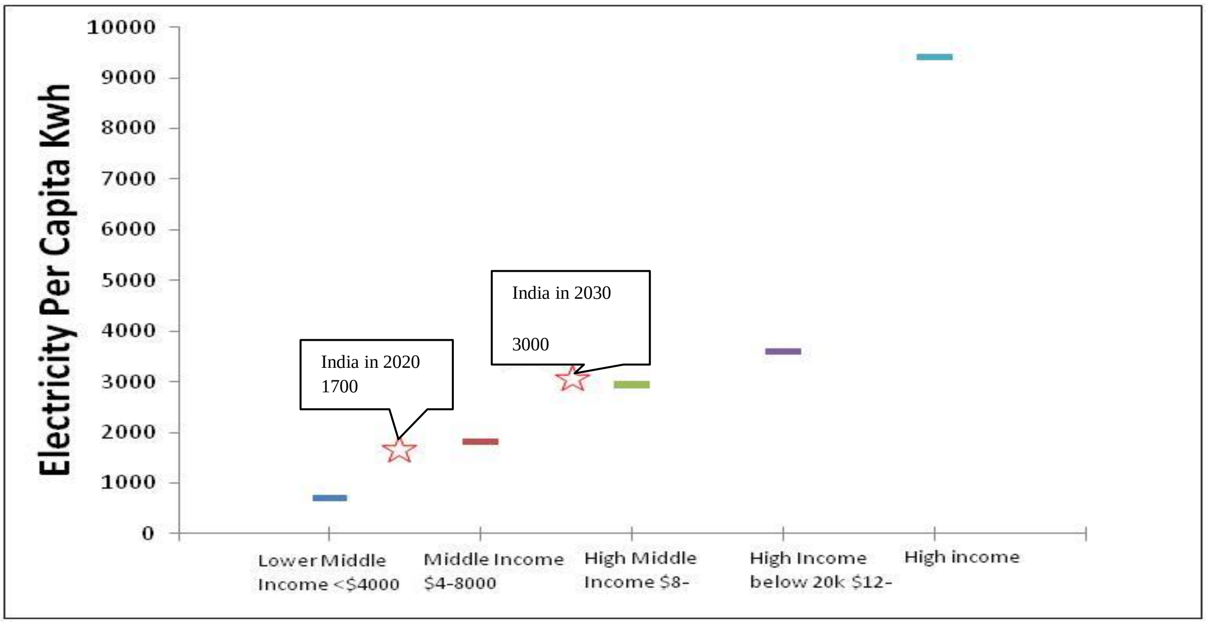
High Electricity Demand Scenario

The high electricity demand scenario is derived through a normative approach. It is important that this demand scenario is understood in the context and limitation for what it was developed: to provide an approximate upper-bound for a high growth scenario.

The high electricity demand reflects aspiration goals for future per-capita electricity consumption based on current observed patterns of electricity consumption across countries. It implicitly does imply that the Indian economy will have to grow in order to realize this demand. But such a normative approach avoids having to make a series of intermediate assumptions on economic growth and the electricity intensity of that growth.

Electricity use within any country represents a wide variety of underlying interrelated factors: income level, the level of economic activity, composition of economic activity, electricity intensity, availability of energy resources, energy costs and supply infrastructure. Though these factors all shape electricity demand in complex interrelated ways, one of the visible relationships with electricity use is income level. A country's per-capita- electricity consumption exhibits strong correlation with its national income level as illustrated in Figure 3.1.

Figure 3.1 Electricity Use and Per Capita Income



Source: World Development Indicators, World Bank

The relationship between electricity per-capita and GDP per-capita were econometrically derived using panel data that included a cross sectional of all countries (with available data for all years), covering 28 years between 1980 and 2008.

For the high demand scenario, the following annual per-capita electricity assumption is used: 1700 kWh by 2020 and 3,000 kWh by 2030. In contrast, India's per-capita electricity consumption for 2011-2012 was approximately 880 kWh and is projected to reach approximately 1,500 by 2020-2021 according to the draft 18th EPS.

The per-capita electricity consumption in the high demand scenario might suggest that by 2020 India would achieve an income level of a middle income country. Similarly, by 2030 India would achieve an income level of a high middle income country. Of course, both of these implicit inferences assume that the relationship between income and electricity demand will continue to hold.

The aspirational high electricity demand may also reflect other factors beyond simple economic growth. The Indian power system is generally believed to have very high levels of latent demand. Latent demand refers to that demand component that go beyond simple unmet demand where consumers may opt for alternate energy sources, such as captive generation source, household generator or even the willingness for blackout. This latent demand arises from the fact that many the purchase decisions of customers already include expectations that there will not be an adequate supply of electricity to meet their needs in the first place.

Higher demand may be possible by bringing more of this latent demand more visibly into the grid. This could happen by increased investments in electricity infrastructure, policy certainty or other factors that allow consumers to build expectations of a more reliable supply of grid supplied electricity. Some of the investments required to bring latent demand into the grid will lead to high

GDP but it may also increase the elasticity of electricity to GDP. The high electricity demand scenario, therefore, builds around a normative approach to capture a set of factors that might influence electricity demand beyond just income growth.

The high electricity demand scenario discussed above is developed at the national level. However, the spatial distribution was modified to describe a future where the variation in the per-capita electricity consumption across the states and union territories reduces over time reflecting our aspiration not only for higher but also more inclusive economic growth. Low levels of per-capita electricity consumption reflect a number of factors: lower income levels, low levels of industrialization, poor access, poor electricity infrastructure and high energy cost. Although each of these factors may play out different across the states, in totality low levels of per-capita electricity consumption is a strong indicator of low levels of the human development index. This scenario essentially represents a view of the future where government programs and other targeted investments may move electricity demand to regions with lower level of human development indicators.

The accelerated growth of electricity demand in states with low per-capita consumption could occur for several different reasons. It could result from accelerated economic growth in any economic sector and this scenario does not seek to establish how that growth may result. The scenario simply suggests a convergence in the distribution of per-capita electricity consumption across the states / union territories over time.

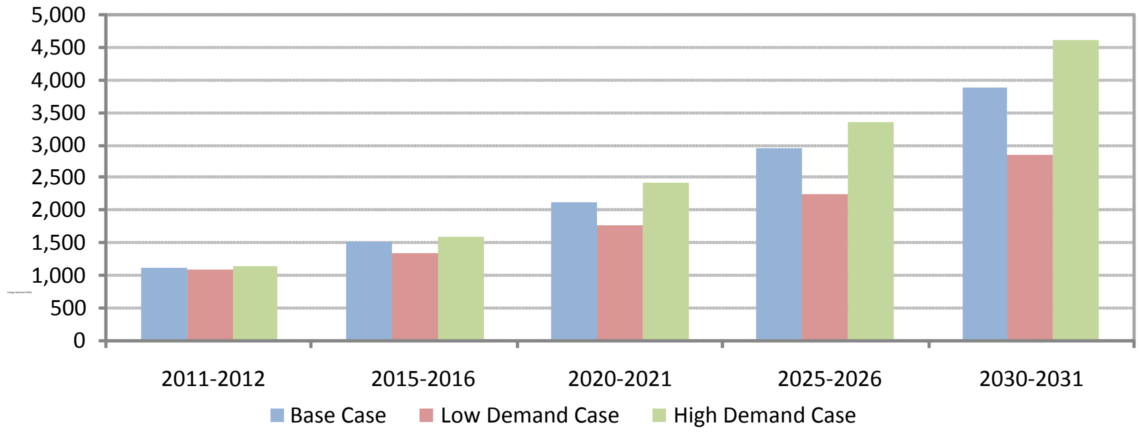
Like the previous scenario, this scenario is derived using the regional distribution in the draft 18th EPS. In this scenario, the standard deviation distribution of per-capita electricity consumption in the draft 18th EPS is reduced by 25 percent in 2020-2021 and by 50 percent in 2030-2031. This has the effect of bringing the states at either end of the distribution closer to the centre without changing the mean of that distribution. The revised distribution of per-capita electricity consumption across the states is then used to parse the all-India demand of the high demand scenario to the state / union territory.

Low Growth Scenario

Based on a number of explorations including brainstorming with informed observers on a variety of risks, both external and internal to India and to the energy system in particular, it is possible with non-negligible probability that energy delivery may not be able to keep up with the requirements of 8-9 percent p.a. economic growth. An iterative process lends credence to consider the possibility of growth grinding down to 6 percent p.a., still far from a worst-case economic scenario, but considered suitable for illuminating some of the strategic choices to be made. Accordingly, a low-case consumption scenario was chosen closely corresponding to the 6 percent case. Indeed this is close to the consensus forecasts for Indian GDP growth in the near-term.

Figure 3.2 shows the energy demand forecast for the three scenarios over the study period.

Figure 3.2 Energy Demand Forecast for the Three Scenarios



Source: ICF International (Model Runs for Working Group)

Chapter 4. Fuel Requirements for Power

Introduction

India is a geographically vast nation with widely dispersed population centres and economic activity that is burgeoning all around the country. As the economy modernizes and diversifies its production base and living standards rise, reliable and affordable access to electricity in requisite quantities has become a critical imperative for sustainable and inclusive growth. Chapter 3 has detailed the requirements for its supply on a state-by-state basis under three plausible scenarios over the next two decades (four Five-Year Plan periods).

The primary energy supplies required to generate electricity include fossil fuels (coal, oil and natural gas), hydropower, fissile nuclear materials and renewable (mainly solar and wind) sources that are available in varying degrees domestically but chronically short of the needs in the aggregate. The current mix (both in terms of installed capacity and actual generation) is dominated by coal with a growing role for natural gas and this is likely to remain so for the next 20-30 years at least. India's coal reserves are concentrated in the eastern states, notably Chattisgarh, Jharkhand and Odisha as well as Madhya Pradesh, Bihar, Andhra and Maharashtra. (Parenthetically it might be noted that a similar situation also holds for natural gas that is currently under exploitation.)

Chapter 2 has described the spatial distribution of domestic energy resources whereby it is clearly evident that energy needs to be transported over fairly long distances to make it available at the locations of electricity demand. Indeed, transportation of coal for power generation accounts for roughly 50 percent of the rail freight in India contributing considerably to the increasing congestion in several key corridors of the railway network. Another telling indicator of the economic salience of this phenomenon is that the cost of transporting coal to distant power generation facilities is often as much or more than the price of coal at the mine.

As alluded to above and is also discussed in the preceding chapter, India confronts an energy deficit and needs to plan to have adequate capacity to meet the demands of a rapidly growing economy and rising aspirations. Energy imports are the preeminent component of our trade imbalance and current account deficits, and a major source of vulnerability to price shocks. Until recently, the concern was focused almost exclusively on the hydrocarbon (petroleum) sector; now attention also needs to be focused on coal availability. Coal imports have grown rapidly in the last few years making India among the top two importers of steam coal whose entry and anticipated role in the international market is cited as a factor contributing to the run-up in prices witnessed a couple of years ago.

There are several implications relating to the transport system. On the one hand it is argued that transport bottlenecks have contributed to unreliability of delivering domestic coal to power plants. Others blame the inability to lift coal from mines (and/or nearby railheads) to be a key factor as well in stagnant output of the collieries. Going forward, however, the bigger issue is to ensure that the transport system which had hitherto focused exclusively on moving domestic coal rapidly expands the coal handling capacities at ports and provides requisite rail connectivity to the demand locations. A strategic question that arises naturally is which ports and how much in terms of their capacity?

Difficult as the questions may be, the complexity pales before the more profound issue of locating the power plants especially when the fact is that two-thirds if not three quarters of the electricity generation capacity that will exist in 2031-32 is yet to be put in place. An obvious question that arises in its most baldly simple form is whether it would not be better to transport energy over long distances as electricity over transmission lines instead of moving coal by rail (or gas by pipeline). The choice, involving a combination of economic, financial, technical and environmental considerations, is not as straightforward as comparing unit costs of transmission versus rail or pipeline transport. In addition to network effects and geographic constraints, additional complexities arise due to major differences in the properties (calorific value, ash and sulphur content) of domestic and imported coal, choice of technology and fuel type, patterns of demand (e.g. peaking) to name some. Yet, given the massive scale of expansion and the high costs involved combined with the scarcity of financial resources and even more the limited capacity to execute, it is imperative that the choices made are those that minimize the aggregate cost to the nation of producing and delivering electricity to the users.

Accordingly a conceptually simple linear programming model has been employed for the analysis. As a first approximation, intrastate movement has been ignored and each state constitutes both a demand centre as well as an electricity supply node. The supply options include in principle all forms of power generation including nuclear and renewable (solar and wind) but these are pre-set at exogenously determined maximum capacity which even at the most ambitious account for a small, almost negligible proportion. While hydroelectric facilities are also included, the focus is on thermal power generation using domestic and imported coal as well as natural gas which differ in terms of their cost parameters. The transport options are surface transport of coal, pipeline for gas and transmission line for electricity; once again the cost parameters derived from existing date differ significantly between the options. Average fuel costs also differ between domestic sources and imports with domestic coal being the cheapest, imported coal and domestic gas (the price of which is regulated) being almost competitive, and imported gas at internationally traded prices being the dearest.

Parameters & Assumptions

The model was run separately for each of the three plausible scenarios for the evolution of future demand as described in Chapter 3. Briefly summarized, the **Base Case** extrapolates to 20 years the 18th EPS forecast for the coming decade that is seen as most credible reference demand projection and represents the most realistic business as usual scenario over the next two plan periods. It also forms the basis for the 12th Five Year Plan. The **Low Demand Case** reflects both demand side and supply side risks, both external and internal to India and the energy system in particular whereby energy delivery cannot keep up with the requirements of 8-9 percent p.a. economic growth. An iterative process lends credence to considering the possibility of growth grinding down to around 6 percent p.a. on average over the next two decades that is still far from a worst case scenario, especially in light the experience over the past year. The **High Demand Case** on the other hand reflects the aspiration to reach Middle Income Country consumption levels (3000 per capita) by

2031. It further assumes more inclusive and equitable patterns of economic development whereby the spatial distribution sees reduced dispersion between states.

Table 4.1 National Annual Aggregate Demand by Scenario (TWh)

Case	2016-17	2021-22	2026-27	2031-32
Base	1516	2118	2938	3857
Low	1329	1736	2228	2808
Aspiration	1591	2422	3334	4603

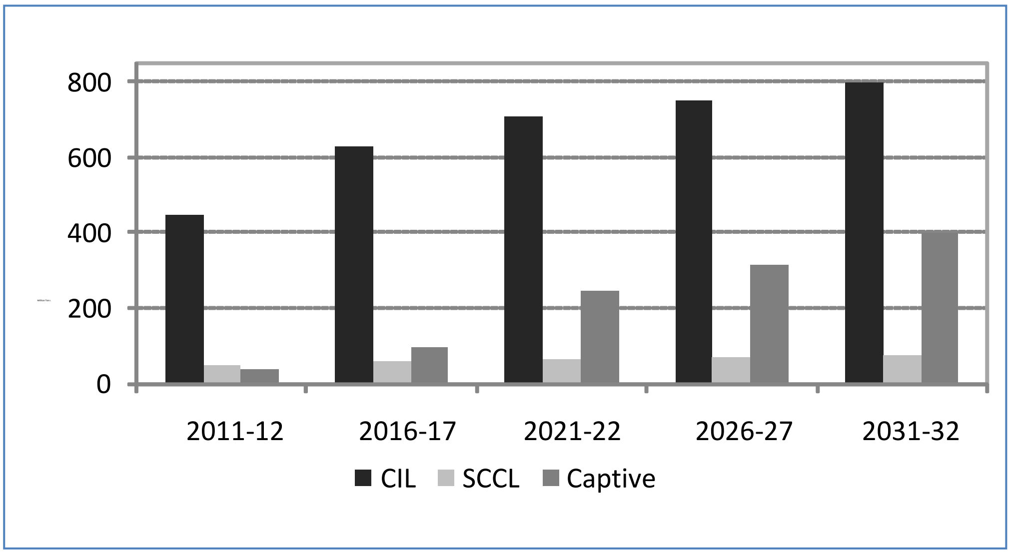
Source: Working Group Research

In order to focus on the strategic issues going forward and provide easiest traction for policy making, every effort was made to ensure consistency with the work done in preparation for the XIIth Five-Year Plan by the various ministries and departments of the Government of India. Detailed documentation is available with the NTDPC secretariat and only the most salient aspects are summarized below.

Capacity Additions: For the XIIth Five year plan capacity additions have been considered as per the latest CEA and MoP plan. This consists of approximately 66 GW of coal based plants plus 1.7 GW of nuclear, 4 GW of gas and 11.5 GW of hydro capacity additions. Renewable capacity is over and above the conventional capacity. State level constraints for capacity additions have been modelled as per CEA for the plans beyond XIIth plan.

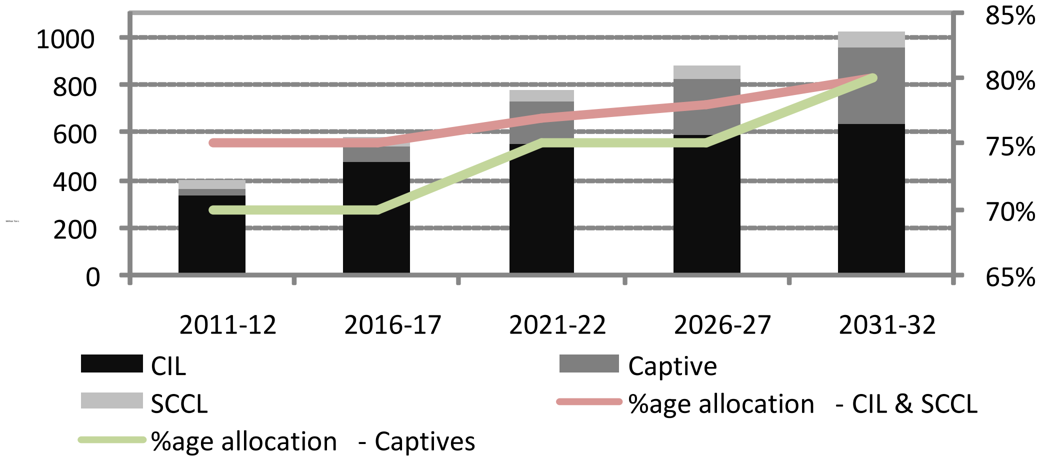
Coal Supply: The percentage of coal allocated from CIL and SCCL to power sector is projected to reach 80 percent by 2031-32 from the current allocation of 75 percent of the total coal production. Allocation to power sector from captives is also projected to reach 80 percent by 2031-32. Lignite coal is also supplied to the power sector.

Figure 4.1 Total Domestic Coal Production (Million Tonnes)



Source: ICF International (Model Runs for Working Group)

Figure 4.2 Coal Allocated to Power Sector (Million Tonnes)

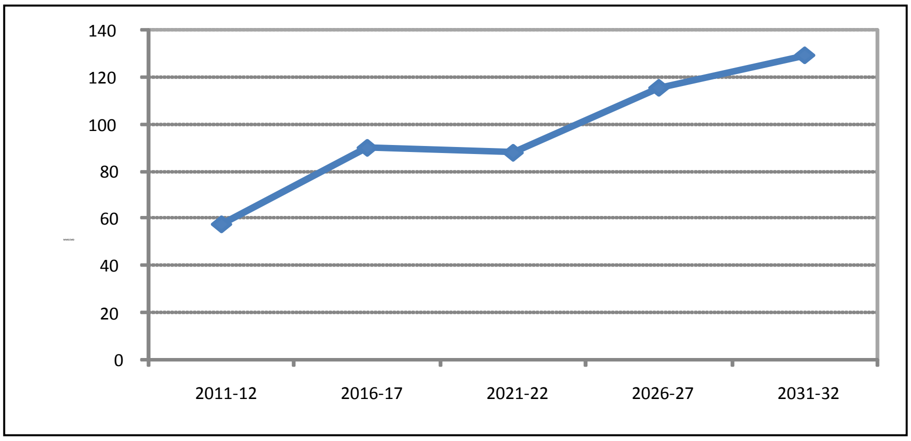


Source: ICF International (Model Runs for Working Group)

Fuel Prices: Coal prices from various subsidiaries are taken as per CIL's notified prices. Imported coal price forecast as per the World Energy Outlook 2011 global coal price forecast and analysis shared by ICF International. Domestic gas prices are as per the prevailing market prices for the various sources (APM, NELP, JVs). LNG prices are based on IEA's WEO forecast for Asian deliveries after adjustment applied corresponding to the actual contractual arrangements available for Indian buyers

Gas Supply: The basis for gas production is the DGH approved gas production plans for various existing and upcoming gas fields. It reflects discussions with and other analyses commissioned for various stake holders including Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum and Natural Gas (MoPNG), DGH, GAIL and others. The longer term projections for the business as usual (BAU) and other gas supply cases (including conventional and un-conventional gas) as well as supply to the power sector is based on international consultants' analysis of gas utilization policy and expectations around supply in the longer term. More specifically, the gas supply share to power sector expected in the range 45-50 percent of the total production.

Figure 4.3 Gas Demand by Power Sector (MMSCMD)



Source: ICF International (Model Runs for Working Group)

Renewable Potential assumptions are mainly driven by the requirement as per renewable portfolio obligations (RPOs) and the generation potential for various renewable energy technologies. The target for the country per the National Action Plan on Climate Change (NAPCC) is that 15 percent of generation should come from renewable energy by 2022. For wind potential, we have taken latest estimates of 109 GW made by Centre for Wind Energy Technology (CWET) for a hub height of 80 meters. Various foreign institutions such as Lawrence Berkeley National Laboratory (LBNL) in the US provide even higher estimates of ~700 - 1,500 GW wind potential for India**.** Solar potential based on JNNSM targets of 22 GW by 2021-22**.** For biomass and small hydro, the potential estimated by MNRE has been used.

Cost Parameters: Average levelised parameters, constant in real terms, have been used for costs of electricity generation, coal mining as well as commodity transport and power transmission have been used.

Preliminary Exploratory Analysis and Further Assumptions

An exploratory analysis to estimate fuel requirements for the power sector was carried out where the objective was to minimize the cost to the nation for generating electricity. Coal plants are designed to run on a certain type of coal with small margins of variation. Therefore, once constructed, plants cannot switch between imported and domestic coal, and plants designed for domestic coal can use only a limited amount of imported coal blended with domestic coal. Recognizing these technical limits on blending, our analysis limited the amount of imported coal that could be blended with domestic coal for all existing units and for new units where the usage of domestic coal has been specified. For plants yet to be built where coal linkage had not been provided (mostly plants to come on-line after the end of the 12th Plan), the type of fuel for which the plant was to be designed was based on economic considerations. Further, once the type of coal (domestic/imported) was selected, no blending was assumed for these later plants.

The findings of the exploratory analyses undertaken to date were startling but, upon reflection, not surprising. Dramatic shifts were seen in the patterns of coal movement. Table 4.2 displays the annual movement of domestic coal into a selection of states at the end of each of the next four Five-Year Plans. While the major increases needed in the railways' capacity to transport coal to U.P and Bihar were noteworthy, the case of Maharashtra and West Bengal posed a conundrum. Should transport capacity be expanded to respond to the needs of the next 5-10 years even when it appears that the assets created may become stranded when the demand disappears in the following decade? Similarly for Gujarat.

Table 4.2: Domestic Coal Movement into States (Mt)

State	2011-12	2016-17	2021-22	2026-27	2031-32
Andhra Pradesh	0	9.1	11.5	-6.1	-8.4
Bihar	7.1	39.0	54.6	51.9	101
Gujarat	17.5	3.8	1.8	0.3	0
Haryana	19.2	20.5	17.6	14.2	19.4
Karnataka	8.7	7.6	11.3	13.0	15.8
Maharashtra	21.8	37.8	31.4	-2.4	-8.8
Rajasthan	16.5	12.4	4.9	3.7	2.2
Uttar Pradesh	44.7	59.2	72.3	78.9	90.3
West Bengal	20.3	12.7	17.5	17.3	-32.4

Source: Model Outputs

The following Table 4.3 sheds further light on the patterns observed and raises other important issues of economic policy. It shows the imports of coal by the same set of states. Unsurprisingly, the imports go to the coastal states such as Andhra, Gujarat and Maharashtra as this minimizes the cost of transport given the overall levels of availability. In later periods, states like Rajasthan that are geographically closer may also use imported coal. The patterns that emerge point to a likelihood of political wrangling as well as issues of inter-state equity with some fiscal ramifications owing primarily to the large differentials in price of domestic and imported coal. One recent signal of times to come is news reports of protectionist noises from resource-rich states.

Table 4.3: Coal Movements (Mt) – Domestic & Imports

State	2011-12		2016-17		2021-22		2026-27		2031-32	
	Dom	Imp	Dom	Imp	Dom	Imp	Dom	Imp	Dom	Imp
Andhra Pradesh	0	5.7	9.1	14.0	11.5	29.1	-6.1	60.2	-8.4	128
Bihar	7.1	3.4	39.0	0	54.6	0	51.9	0	101	3.2
Gujarat	17.5	8.6	3.8	26.9	1.8	47.6	0.3	78.7	0	99.9
Haryana	19.2	0	20.5	0.1	17.6	0.1	14.2	0.2	19.4	0.2
Karnataka	8.7	6.3	7.6	6.6	11.3	6.3	13.0	6.0	15.8	5.7
Maharashtra	21.8	10.8	37.8	31.1	31.4	41.7	-2.4	89.2	-8.8	95.9
Rajasthan	16.5	0.4	12.4	6.3	4.9	6.4	3.7	9.4	2.2	29.0
Uttar Pradesh	44.7	0.2	59.2	0	72.3	0	78.9	2.1	90.3	0
West Bengal	20.3	1.3	12.7	1.1	17.5	1.1	17.3	1.1	-32.4	0

Source: Model Outputs

Modification of Assumptions for More Realistic Scenarios

The preliminary analysis included limits on the amount of capacity that can be added per year, both on a national level and on a state-by-state basis. However, these constraints were refined to prevent excessive concentration of power plants in some states. Such constraints were added to reflect limits due to limited land and water availability and to prevent further environmental degradation in areas that are already critically polluted. More importantly, political economy considerations alluded to above suggested that at least half of the incremental power consumption in each state in each Plan period be constrained to be supplied by generation capacity within that state. This led to a significant change in the location of facilities and the pattern of energy flows. ***The findings and insights that are discussed in the rest of this chapter are based on these more realistic assumptions.*** Annex III.4.1 summarizes one critical dimension, namely the sharp differences in the mix between use of domestic and imported coal in some of the most affected states, most the notably the coastal states such as Andhra and Gujarat.

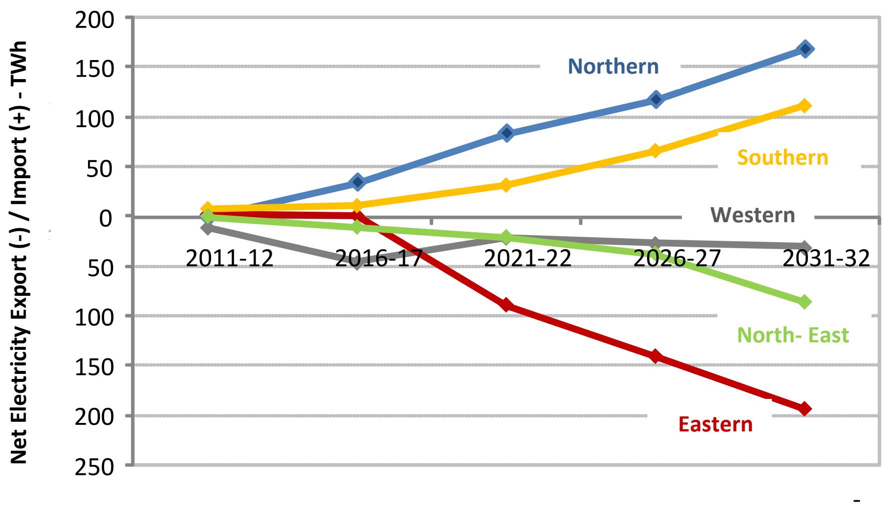
Findings and Insights from the Analysis

The key outputs from the modeling and analytical effort comprise the state-wise generation of electricity and the associated sources of primary energy. Since our focus is on transportation requirements particularly of coal, the presentation below is confined to flows of electricity and movement of coal both in terms of domestic coal and imports.

Base Case

In the base case scenario, the Northern and Southern regions with their burgeoning demand become major importers of power while the Eastern region emerges not only as a supplier of coal but also as an exporter of electricity as power generation plants are located near the mines. Odisha, for example, is expected to see a massive increase in electricity generation. The North-Eastern (in light of its hydropower potential) and Western regions also export electricity but much less than the major Eastern states.

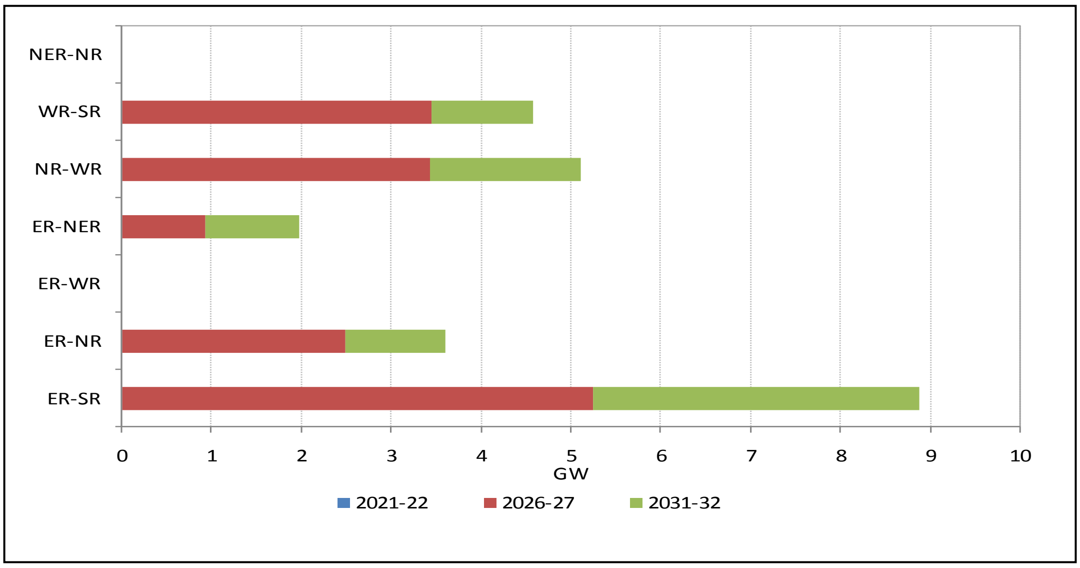
Figure 4.4 Inter-Regional Electricity Transmission Flows



Source: ICF International (Model Runs for Working Group)

The expected pattern of electricity flows in the base case scenario point to a major need to expand transmission capacity not only from the Eastern region but also from the Western to the South and North as shown in the figure below. As discussed subsequently, however, the patterns change substantially under the other scenarios so a robust risk analysis is advisable to prioritize and program transmission capacity investments. More so, in view of the need to also maintain grid balance.

Figure 4.5 Transmission Capacity Additions

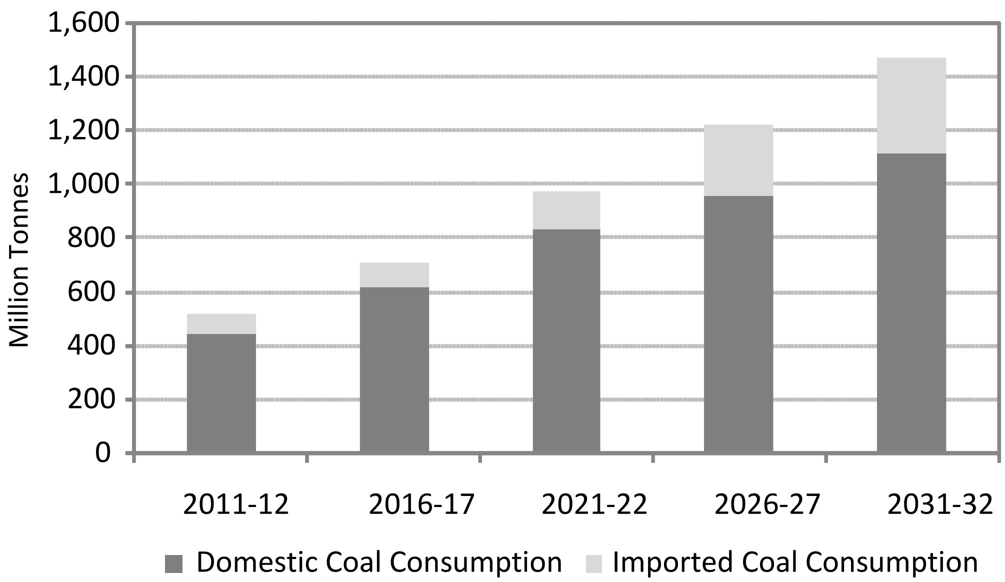


Source : ICF International (Model Runs for Working Group)

Increasing reliance on imported coal

Domestic coal supply growth (including captive and Lignite) is not sufficient to meet the increasing demand. Imported coal makes up for the shortages in domestic supply. Demand for imported coal rises from ~74 MT in 2012 to ~355 MT by 2031

Figure 4.6 Consumption of Coal (Mt)



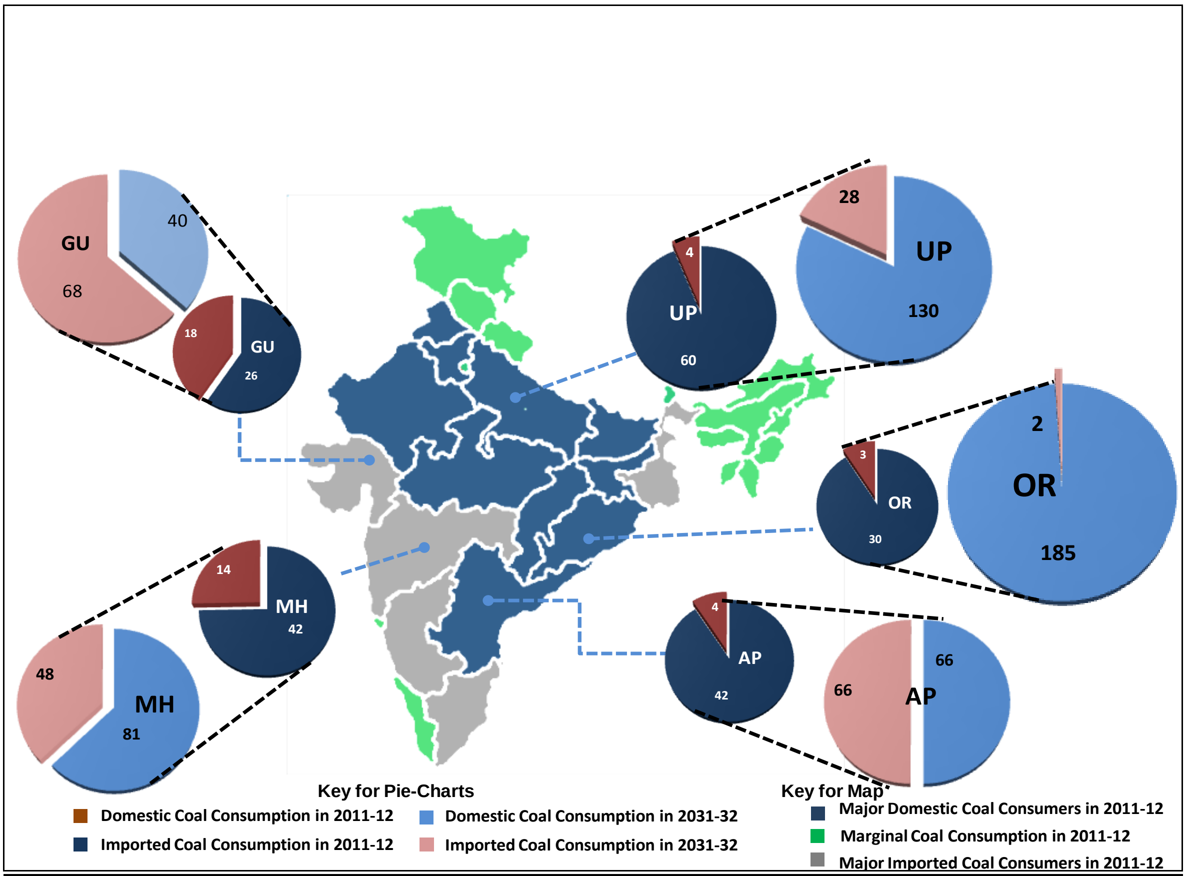
ICF International (Model Runs for Working Group)

The changing mix between imported and domestic coal varies considerably between the states as depicted in the figure below. In addition to Gujarat and Maharashtra which are already importing coal for power generation, Andhra Pradesh emerges as a major destination of imported coal which accounts for half the total coal consumed. (Indeed in the unconstrained case, the share of imported coal is much higher.) The logic is straightforward, importing coal directly to the coastal states minimizes the transport costs by avoiding land transport over long distances.

States such as U.P. which are far away from the coast also need imported coal because domestic suppliers are unable to meet the large increase in demand. Thus not only is there a need to dramatically expand the capacity of ports to handle the massive increases in coal imports but also to ensure rail connectivity to deliver in the hinterland.

Figure 4.7 Base Case State-Wise Coal Consumption – 2011-12 and 2031-32

(All numbers are in Mt)



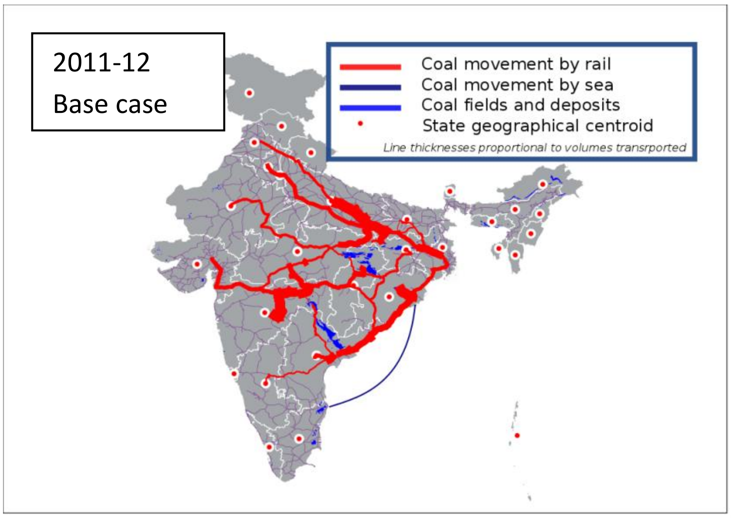
Source: ICF International (Model Runs for Working Group)

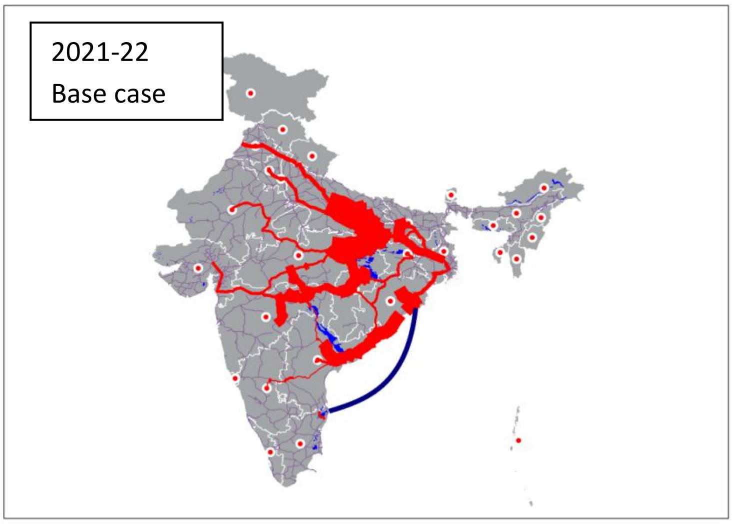
Movement of Domestic Coal by Surface Transport

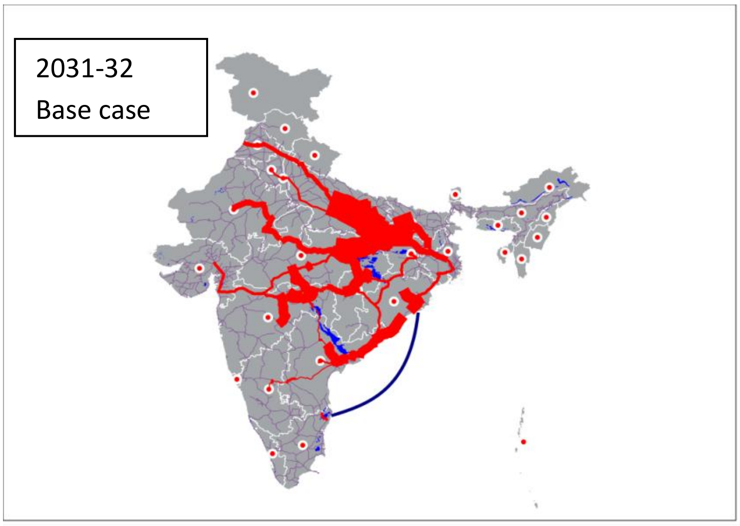
The analysis also yields considerable insight in terms of planning priorities. Figure 4.8 for the base case depicts the volumes of coal movement required over the next decade and the following one. It shows the dramatic increase in the volume of coal transported, mainly in the eastern states over each of the next two decades. In addition, the volumes for some routes fluctuate. For example, the volume of coal transported to Rajasthan from the East decreases in 2021-22 and then increases by 2031-32. Further, the volume for some destinations such as the Western states of Gujarat and Maharashtra remain fairly constant over the two decades, the growth in electricity generation in those states fired by increased imports of coal.

Some salient implications of the transport pattern for coal that emerge from these results. First is the high priority needed to address the infrastructure requirements needed to enable the flows depicted in 2021. Given the gestation periods in constructing rail links, these projects need to be undertaken now. In particular, the Eastern Freight Corridor and the links to it from the mining areas needs urgent action for expeditious progress. Second, the differences between the requirements over the two decadal periods suggest some caution and suitable risk analysis to guard against the possibility of stranded assets due to major shifts in patterns of supply. (See also the discussion below of the coal movement patterns under the other two scenarios.) Such risks can be hedged though choice of alternative routes. Third, in light of the large volumes in flows to the eastern coastal states indicates the promise of coastal shipping as the preferred mode of transport especially because it may be able to expand more rapidly than rail links. Moreover, there may be efficiency gains in coordinating the investments with the expansion in capacity of dedicated coal terminals to handle imports. Of course, that may not be possible if separate ports and/or terminals are set up for coastal shipping. This issue is discussed at greater length in Chapter 6.

Fig 4.8 Comparison of Coal Movement (Base Case)





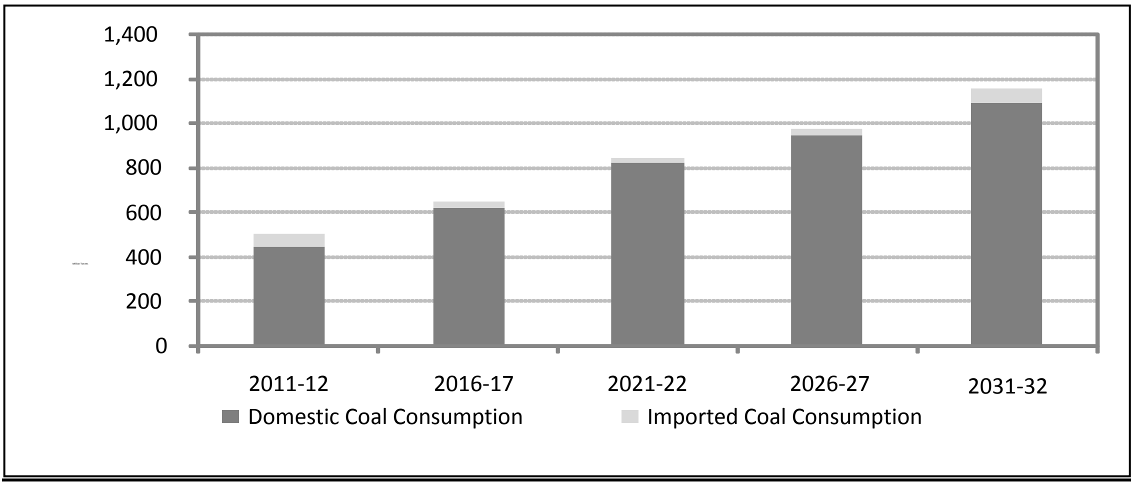


***Source: Working Group* Research**

Low Case

In the low case scenario, a preliminary iterative and investigative analysis suggested that if the imports of coal were constrained to the present level, then the electricity requirements compatible with a lower rate of economic growth, around 6 percent, could be met. Thus in this case, domestic coal almost meets the overall increase in coal requirement in the country. Southern states will need to rely on domestic coal based generation from Eastern and Western States and hence their dependence on other states for electricity will be higher compared to the base case

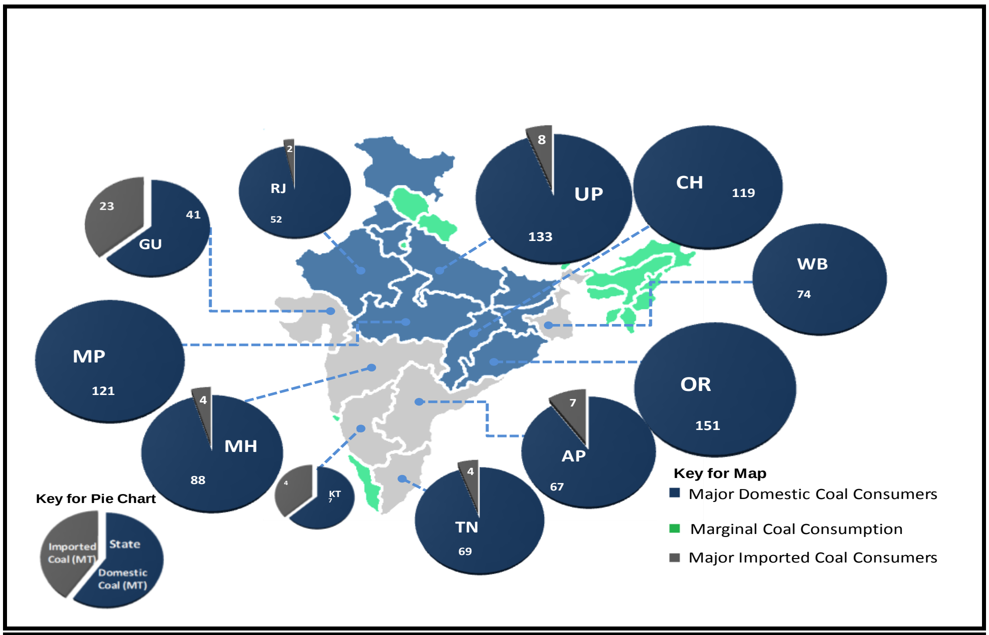
Figure 4.9 Coal Consumption – Low Case (Mt)



Source: ICF International (Model Runs for Working Group)

Figure 4.10 State-wise Coal Consumption – 2031-32 (Low Case)

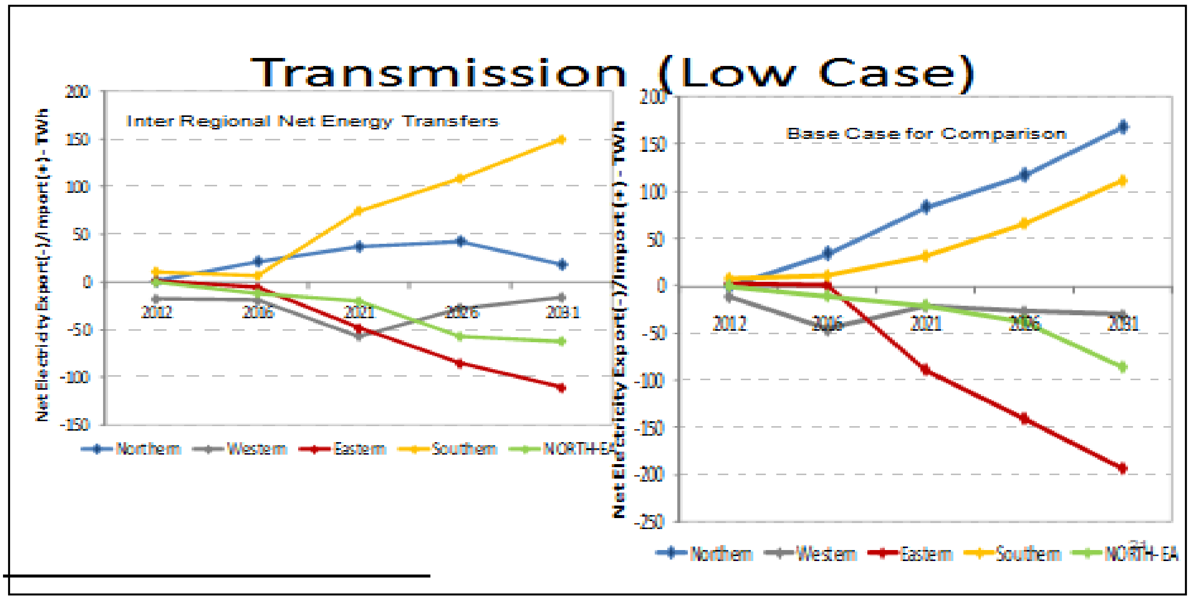
(All numbers are in Mt)



Source: ICF International (Model Runs for Working Group)

In this low demand growth scenario, the dependence of Northern states on other states for supply of electricity is expected to be low compared to the base case. Accordingly, most of the transmission capacity required has to be built towards the southern region.

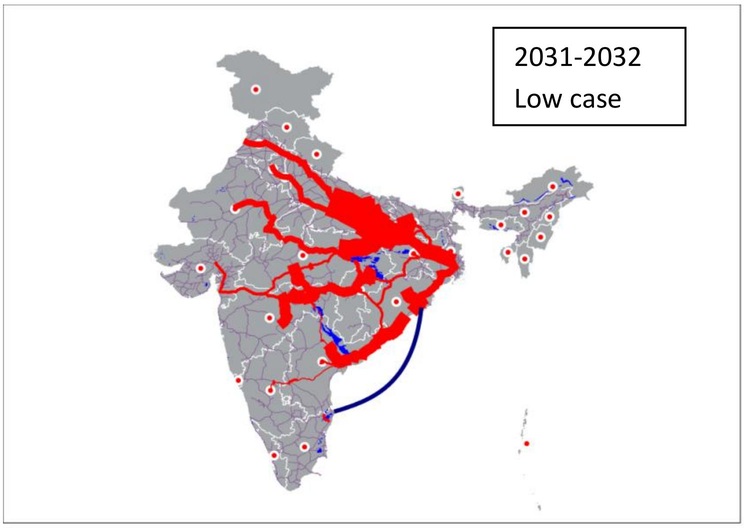
Figure 4.11 Transmission (Low Case)

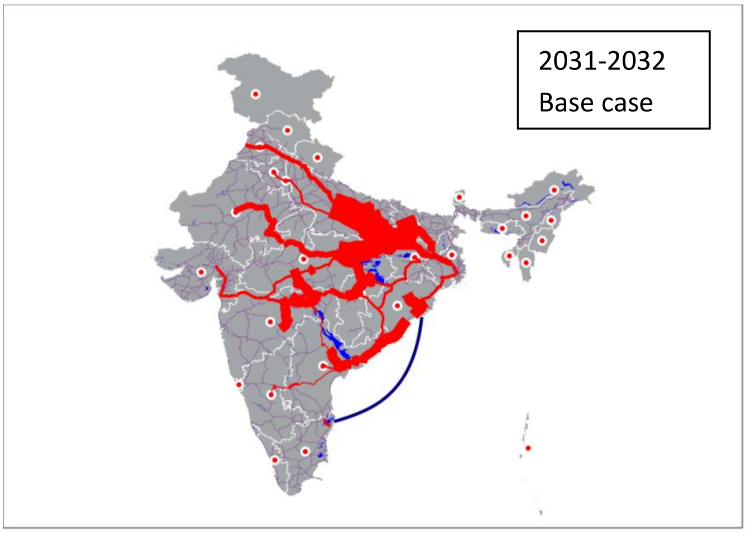


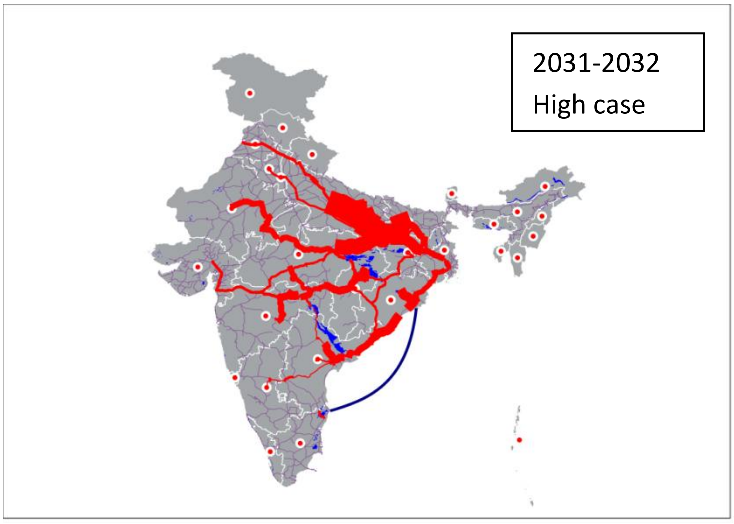
Source: ICF International (Model Runs for Working Group)

A significant and counter-intuitive result emerging from the analysis is that under the low growth scenario the actual movement of domestic coal actually is larger putting even more pressure on the rail freight system. The logic becomes readily apparent in hindsight: the decrease in coal use is mainly that of imports which would typically land near the demand centres in the coastal states. Domestic coal is utilized in the same volumes as in the other cases but in the low case has to move longer distances to more far-flung locations thus increasing the surface transport burden. The economic salience of this phenomenon is increased further when one considers that the low growth scenario also corresponds in all likelihood to one where public resources are more constrained and infrastructure bottlenecks more severe.

Fig. 4.12 Comparison of Coal Movement in 2031-32 in the Three Scenarios







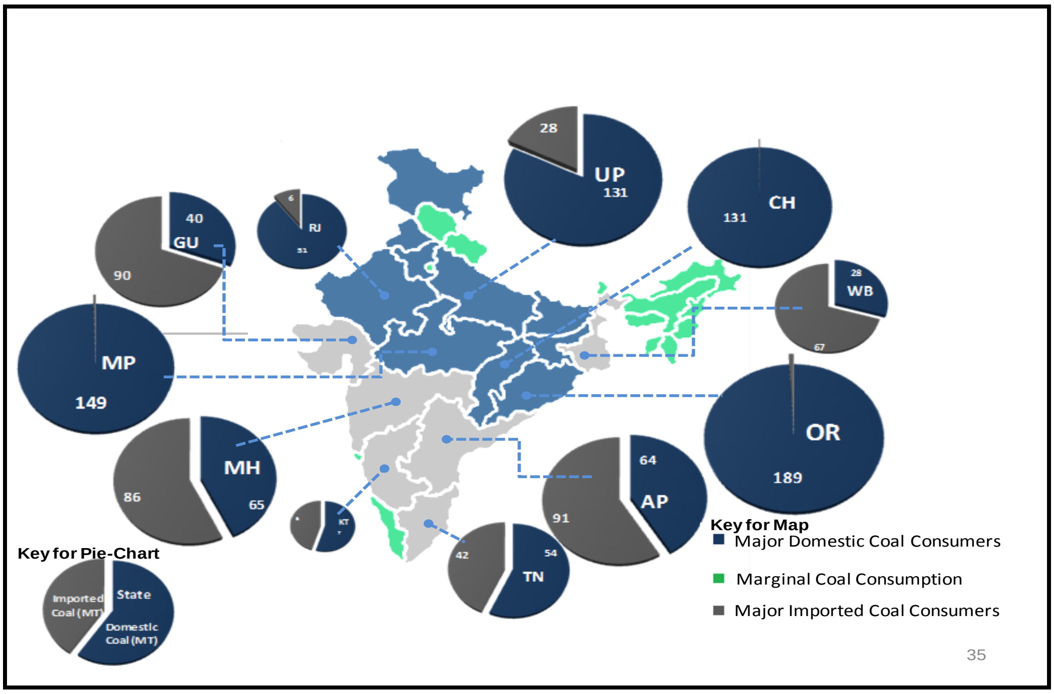
Source: Working Group Research

High Case

The High Case scenario recognizes that the Base Case itself involves considerable stretch on the supply of infrastructure as well as availability of financial resources. Accordingly, to maintain a healthy realism and to also factor in the tremendous and hitherto under-tapped potential of new technologies to increase efficiency and increase the market penetration of renewable energy, certain assumptions on the supply side of the system were also modified. Specifically, the share of renewable energy is projected to rise to 18 percent in 2031 and an additional increase of 1 percent every five years is incorporated in power generation. Gas supply is also projected to be larger.

Nevertheless, in this scenario, coal imports grow more dramatically and go to coastal states. The Southern region also becomes exporter of electricity while the Northern region alone remains an importer of electricity. The figures below depict the highlights of coal consumption in different states, electricity transmission flows and finally the movement of coal by surface transport. A major implication is the need to expand port capacities even faster to handle coal imports.

Figure 4.13 State-wise Coal Consumption – 2031-32 (High Case)



Source: ICF International (Model Runs for Working Group)

Overall Observations

Annex III.4.2 shows the generation capacity mix and energy mix for the three scenarios in more detail. Some conclusions emerge from those results:

- Coal continues to dominate the energy mix. Its share of the total electrical energy generated declines slightly from 68 percent currently to 65 percent, 62 percent and 60 percent in 2031-32 in the base, low and high case respectively.
- Coal continues to dominate the capacity mix also. However, its share of the capacity mix declines more rapidly than its share of the generation mix. Currently it is about 55 percent and declines in 2031-32 to 45 percent for the base and low case and 37 percent in the high case.
- Natural gas share of the energy mix declines for all three scenarios because it is increasingly used as an intermediate resource in the dispatch order instead of as a baseload resource as done currently.

Annexes III.4.3 to III.4.9 provide additional state-wise or region-wise details for the terminal years for each of the next four five-year plans for: consumption of domestic coal; consumption of imported coal; consumption of natural gas; conventional generation capacity; renewable energy capacity; and net transmission.

Domestic Coal Usage

Table 4.4 below shows the domestic coal usage. It remains the same in all three scenarios because domestic coal is the least expensive fuel for electricity generation and is used first to meet the nation's electricity requirements. After domestic coal available in a particular is exhausted, other fuels are considered by the model.

Table 4.4 Consumption of Domestic Coal for the Power Sector (Mt)

2011-12	2016-17	2021-2022	2026-27	2031-32
442	614	828	951	1,112

Source: ICF International (Model Runs for Working Group)

The amount of coal that is needed for the power sector even today is large, and it will grow about three-fold by 2032. Movement of these amounts of coal will require increasing amounts of rail infrastructure for transportation which poses great challenges for the Railways which are already strained to provide adequate transportation service. Coal beneficiation (also known as coal washing) is one way that the transportation requirements can be reduced. However, nothing comes without some additional costs. The box on coal beneficiation describes the benefits and some of the environmental costs of coal beneficiation.

Box 4.2 - Coal Beneficiation

The intrinsic quality of Indian coal and the way it is mined results in the coal delivered by mines to be of poor quality. It has high ash content and contains extraneous material such as shale and sandstone. Transport of run-of-mine (ROM) coal is wasteful because the extraneous material and ash are also transported with the coal. Coal Beneficiation (also known as coal washing) is a process by which the quality of coal can be improved, by either reducing the extraneous material or reducing the ash content or both.

Coal beneficiation is usually done by crushing the coal and putting it in a liquid in order to separate the lighter coal (low ash content) from the heavier coal (high ash content) and the extraneous material. Because beneficiated coal has a higher calorific value, transport costs are reduced. In addition, there are many benefits for power plants, such as:

- Reduction in the required size of the power plant because less coal is required to produce the same electrical output.
- Better performance because of greater uniformity in the coal that is used.
- Reduction in wear and tear because extraneous material has been removed.
- Reduction in the amount of fly ash that is produced.

The Ministry of Environment and Forests (MoEF) issued a notification requiring that the following power plants to use coal with an ash content of 34% or less with effect from June 2001 which was later extended to June 2002:

- Power plants at a distance greater than 1,000 km from the pit head; (MoEF has proposed an amendment to reduce the distance to 500 km. CIL has to ensure that there are enough washeries to meet this stipulation (MoP,2012: 45)
- Power plants located in critically polluted areas, urban areas and ecologically sensitive areas;
- Power plants using fluidized bed combustion (CFBC, AFBC and PFBC) and integrated gas combined cycle (IGCC) technologies were exempted from this requirement.

Beneficiation results in some loss of coal. The yield decreases as the level of washing is increased. The optimum level of beneficiation depends on several factors: cost of beneficiation; yield; price of unbeneficiated (ROM) coal; economics of the power plant; distance to the power plant; and transportation costs. Therefore, it is difficult to give a single number for the savings in transportation costs. However, for typical Indian coals, the estimated savings in transportation costs for moving coal 1000 km are about 10-12% (MoC, 2012; Anderson and Nowling, 2012).

While beneficiation of coal provides many benefits, it also imposes severe stresses on the environment.

Beneficiation is usually done through a wet process that uses a lot of water which can be a problem in water-scarce areas. More troubling, the used water gets polluted with coal dust and harms the local environment. The use of dry processes is being explored, and they may provide better performance but at a higher cost. There is not much experience with these processes yet.

Rejects from beneficiation are often not properly disposed off, and they degrade fertile land and are susceptible to spontaneous combustion. Earlier efforts to burn rejects using fluidized bed combustion (FBC) were not very successful. More recently, private sector FBC plants are reported to be operating successfully (MoC, 2012).

There is about 44 GW of capacity at a distance of more than 1000 km and it would require about 175 Mtpa of beneficiated coal to comply with MoEF's notification. If the distance is reduced to 500 km, about 90 GW of capacity would require about 360 Mtpa of washed coal. Existing capacity for coal beneficiation is insufficient. Currently coal beneficiation capacity is 96 Mtpa for non-coking coal (SG-2 report, 2011), although it is operating at about half its capacity (based on CCO, Coal Directory, 2010-11) Coal India Ltd (CIL) has plans for adding 20 new washeries with a total capacity of 111 Mtpa of which 19 Mtpa will be for coking coal and the remaining 92 Mtpa for non-coking coal. Together, this capacity could theoretically be just sufficient to fulfill the requirements of MoEF.

Beneficiated coal is not being used by power plants due to factors on both the supply and demand side. Suppliers of washed coal see very little incentive for producing washed coal. There have been conflicts between CIL and its customers over who should bear the costs of washing. On the other hand power plants do not demand washed coal because there is no penalty for not complying with MoEF's directive.

Imports of Coal

Table 4.5 shows consumption of imported coal for states that consume more than 3 Mt in any year and under any of the three scenarios. The amount for the entire country is also shown in the last row. The total imports of coal are expected to grow dramatically; almost five-fold over the next two decades in the base case, and six-fold in the high case. As can be seen from Table 4.5, most of the imported coal is expected to be used in the coastal states: AP, Gujarat, Maharashtra, Karnataka, Tamil Nadu and Bengal. However, there are other states such as Haryana, Punjab, Rajasthan and UP that are also likely to be significant consumers of imported coal.

Table 4.5 Consumption of Imported Coal for Select States (Mt)

	Base Case					Low Case					High Case				
States	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**
AP	4	11	27	49	66	4	5	5	5	7	4	12	28	54	91
BI	1	3	1	1	1	0	0	0	1	1	1	3	1	9	15
CH	2	7	0	0	0	0	0	0	0	0	3	11	0	0	0
GU	18	22	43	59	68	18	16	14	16	23	19	31	47	60	90
HY	4	2	6	13	17	4	0	0	0	5	4	2	9	12	18
KT	7	7	6	6	15	7	3	2	2	4	7	7	5	5	6
MH	14	20	17	35	48	12	2	3	3	4	14	20	17	43	86
PB	0	2	2	7	9	0	0	0	0	3	0	2	3	7	8
RJ	2	4	6	15	5	2	1	1	1	2	2	4	6	6	6
TN	4	5	24	37	47	4	0	1	1	4	4	8	15	35	42
UP	4	0	4	28	28	2	0	0	0	8	4	0	7	32	28
WB	6	1	1	14	48	**6**	**0**	**0**	**0**	**0**	6	2	18	29	67
India	**73**	**88**	**138**	**266**	**355**	**61**	**28**	**27**	**28**	**61**	**76**	**106**	**158**	**295**	**460**

Note: Only states that consume more than 3 Mt in any year under any of the three scenarios are shown in this table. Therefore, the total of these states will be less than the amount shown for the entire country in the last row.

Source: ICF International (Model Runs for Working Group Research)

Handling Uncertainties

As we have seen in looking at the three scenarios, there can be great variation in both the amount of coal to be transported and the pattern of the movement. This variation could be triggered by changes in the rate at which the economy is growing, greater use of renewables, increased availability of gas or higher energy efficiency.

Given this uncertainty, it is important that planning for bulk transport of energy commodities be adaptive. A strategic bulk transport planning group should be established that monitors developments and potential developments in coal and other fuel markets, renewable energy technologies, and domestic fuel supply. In response to changing conditions it should periodically (say every five years) direct changes in the plans for transport of fuels so that adequate fuel supplies are available to power plants without delay and at low cost. The group should include all major stakeholders and representatives from power, railways, and natural gas sectors.

In a working paper on *Institutions for Transport System Governance* done for NTDPC, it has been proposed that an Office of Transport Strategy (OTS) that would integrate transport planning across modes and coordinate between the Ministries and other levels of government. Two options are proposed for locating OTS: (1) creating a new entity linked to the Prime Minister's Office (PMO) or the Cabinet Secretariat; or (2) restructuring the Planning Commission Transport Division for this purpose. The strategic bulk transport planning group could be established under OTS and OTS could extend coordination to non-transport Ministries such as power, petroleum and natural gas, and steel on issues related to transport of bulk commodities.

Summary

In order to understand the implications for transport of coal for electricity generation, three scenarios – base, high and low – were analyzed using a model for the power sector. Because domestic coal is the least expensive fuel for electricity, in each of the scenarios the entire amount of domestic coal available was used first, and hence the consumption of domestic coal in the scenarios was the same and was about 1,100 Mt in 2031-32. Naturally, the amount of imported coal used was quite different in the three scenarios to account for the differences in the amount of electricity produced.

The volume of coal transported increases quite dramatically over each of the two decades, particularly in the eastern part of the country. A counter-intuitive result is that under the low growth scenario the actual movement of domestic coal actually is larger putting even more pressure on the rail freight system. This is because as growth slows, domestic coal is not required to the same extent closer to the producing area and is available to be sent to areas further away, thus reducing imports of coal. This increases the burden on the rail transport system, unfortunately right when public resources are more constrained.

Given the very large increase in the volume of coal that will have to be transported particulary in the eastern part of the country and on the route that will be covered by the Eastern DFC (Kolkata – Ludhiana), it is imperative that capacity enhancement begin immediately. The Eastern DFC should get priority and the eastern end should be constructed first because that is where traffic will be the heaviest.

As we have seen, the pattern of traffic could be quite different depending on how the economy performs. Therefore, coordination will be required between the Ministries of Power, Coal and Railways. In addition, planning will have to be adaptive to the extent possible.

Chapter 5. Transport Requirements for the Petroleum, Natural Gas and Steel Industries

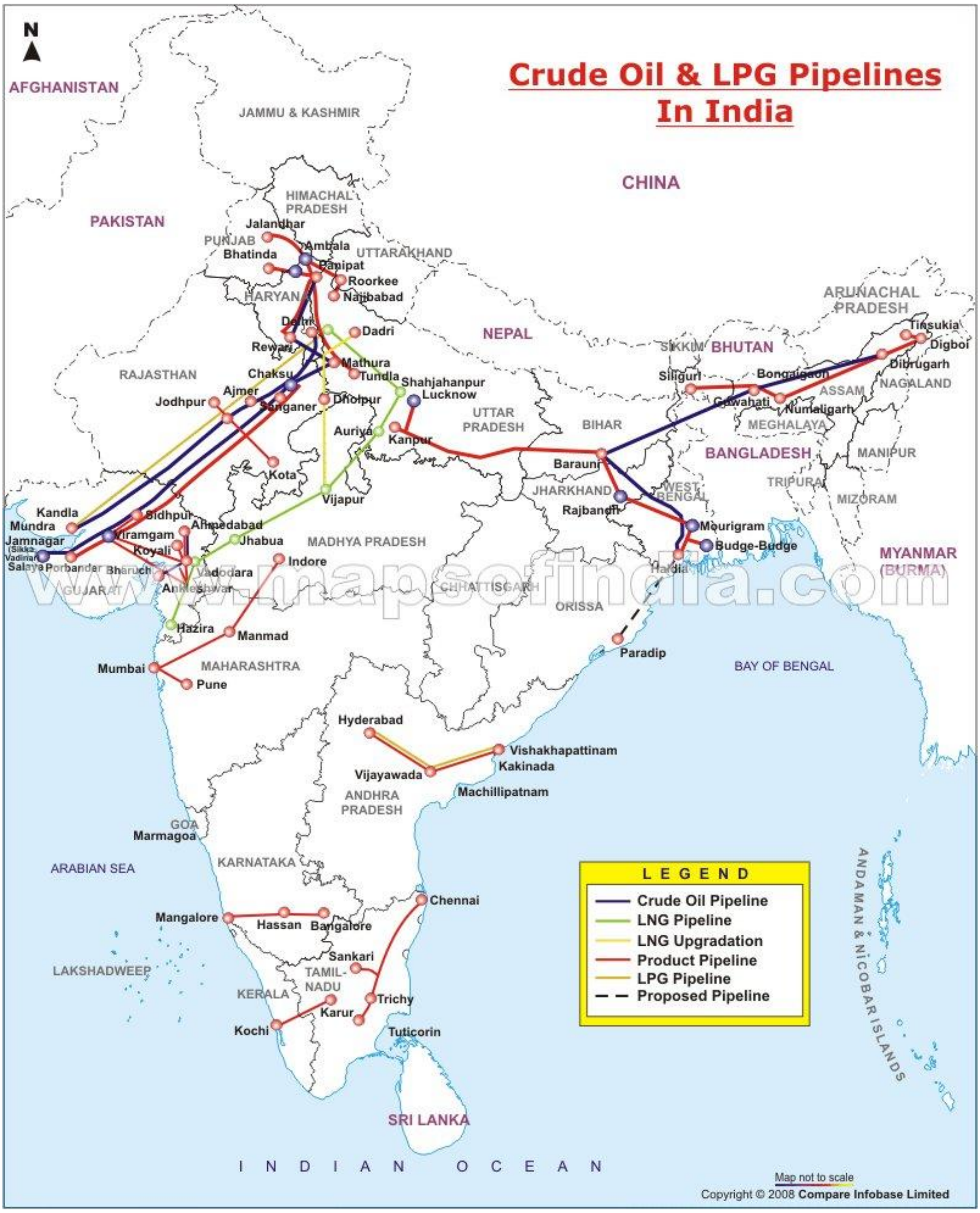
In India, all the natural gas and a major part of petroleum and petroleum products are transported by pipelines. Even though some fraction of petroleum products are transported by rail, the amounts are insignificant compared with the amount of coal that needs to be moved, and therefore do not have much of an impact on the railway infrastructure required for movement of bulk commodities. The main intention for looking at the transport requirements for the petroleum and gas industry is to check the adequacy of the infrastructure particularly for gas to ensure that sufficient transport capacity is available for the power sector. Transportation for the petroleum industry covers the movement of crude oil from oil wells or ports to refineries, and the movement of petroleum products from refineries to the retail outlets.

In contrast, the steel industry relies mostly on railways for transport of raw materials and finished steel. In fact, the transport requirements of the steel industry are a significant component of the traffic for railways and ports. In this chapter, we assess how much material needs to be transported for the steel industry. The resulting infrastructure requirements are covered in Chapter 6.

Crude Oil

Crude Oil is moved either by pipeline or coastal shipping to the refinery depending on the location of the source. Crude from onshore oil fields is mainly transported through pipelines, while coastal ships are primarily used for moving crude oil from offshore oil fields. Road and rail are not used in transporting the crude oil. At present there are 16 crude oil pipelines in the country with length of 8,560 km and capacity of 107 Mtpa, shown in Figure 5.1 which also shows pipelines for other petroleum products that we discuss later. A complete list is given in Annex III. 5.1. The crude oil pipelines are in the North-Western and Eastern parts of the country, and most of the crude they carry is for the PSUs. The PSUs transport roughly half their crude through pipelines while private companies transport very little through pipelines and mostly by coastal shipping (see Table 5.1).

Figure 5.1 Crude Oil Pipelines in India



Source: Maps of India (2013)

The demand for crude oil is expected to increase from 210 Mt in 2011-12 to 286 Mt at the end of the 12th Plan and 353 Mt at the end of the 13th Plan (2021-22) with new refineries at Gujarat, Maharashtra and Tamil Nadu in the next decade, and expansion of 55 Mtpa at existing refineries proposed during the 13th Plan. In order to optimize the crude mix and product pattern to ensure adequate profitability of the companies, crude oil will be sourced from various producing nations in addition to domestic fields.

The year-wise estimate for movement of Crude Oil through Coastal and Pipelines both by PSUs and Private Companies is as shown in Table 5.1.

Table 5.1 Modes of Transport for Crude Oil (Mt)

Year	PSUs			Private Companies		
	Pipelines	**Coastal Shipping**	**Total**	**Pipelines**	**Coastal Shipping**	**Total**
2011-12	70.2(52)	64.8(48)	135	8.25(11)	66.75(89)	75
2016-17	84.6(45)	103.4(55)	188	8.82(9)	89.18(91)	98
2021-22	97.99(41)	141.01(59)	239	10.26(9)	103.74(91)	114
2026-27	116.66(38)	190.34(62)	307	12.24(9)	123.76(91)	136
2030-31	146.68(38)	239.32(62)	386	15.3(9)	154.7(91)	170

Note: The figures in parenthesis are percentage shares

***Source: Ministry of Petroleum and Natural Gas*, (2012).**

With a number of refineries coming up at ports, the share of movement of crude oil by coastal shipping is expected to increase from 65 percent in 2010-11 to 73 percent by 2031-32.

Investment Required

Table 5.2 below lists the new pipelines for crude oil that are proposed or are already under construction. The total length of new pipelines is about 830 km as shown in the table. Based on the estimated cost of Rs 2.5 – 3.0 crore per km (MoP&NG note on costs, 2012), the total cost for these new pipelines is expected to be Rs. 2000-2500 crore.

Table 5.2 Proposed or Under Construction Pipelines for Crude Oil

Pipeline Name	Length (km)	Capacity (Mtpa)	Status
De-Bottlenecking of SMPL	767	4.0 (21 to 25 Mtpa)	Under Implementation
Augmentation of PHBPL	64	4.2 (11 to 15.2 Mtpa)	Under Implementation
Augmentation of SMPL		10 (25 to 35 Mtpa)	Planned for 12th & 13th Plans
Augmentation of Mundra-Panipat PL		3.6 (8.4 to 12 Mtpa)	Planned for 12th & 13th Plans
TOTAL	831		

Source: Ministry of Petroleum and Natural Gas (2012b)

Petroleum Products

Petroleum products comprise Petrol, Diesel, ATF, Naphtha, Fuel Oil, Bitumen, LPG, lubricants and paraffin wax, petroleum coke etc. The movement of these products from refineries to retail outlets is carried out using the least cost mix of rail, coastal shipping, roads and pipelines. The primary movement of petroleum products, from refineries to depots is through pipelines, rail or coastal shipping. The secondary movement of petroleum products i.e. from depot to the retail outlet, viz. *last mile is* necessarily through roads, irrespective of the mode used for the primary movement.

In comparison with rail and road, pipelines are considered much more economical. Indian Oil Corporation Ltd. (IOCL) estimates for 2010-11 that the cost of movement was Rs 0.34/Mt-km for movement through Pipelines, Rs. 1.39 per Mt-km by Rail and Rs. 2.86 per Mt-km by Road. The per-unit cost advantage explains the economic importance of investment in pipelines for movement of oil and gas, in addition to their safety and environmental friendly approach. Consequently, since 2008-09, there has been substantial investment in pipeline infrastructure. At present there are 31 product pipelines with a length of 11,274 km and capacity of about 70 Mt. In addition, there are LPG pipelines of 2,313 km with capacity of about 4 Mt. These pipelines are shown in the map in Figure 5.1 and also listed in Annex III. 5.2.

Table 5.3 gives the inter-modal mix of transport of petroleum products in 2010-11 and the next two decades for only primary movement of petroleum products. As shown, the share of pipelines for transport of petroleum products is about 30 percent. This is considerably less than other countries such as the USA and China. In the US, 59 percent of petroleum products were transported through pipelines followed by Coastal (33 percent), Road (5 percent) and Railways (3 percent).

Broad industry projections suggest that movement of POL products by PSUs through Pipelines would be around 55 percent, Coastal- 15 percent, Rail- 24 percent and Road at 5 percent by 2031-32. It is worthwhile to note that the share of pipelines in transportation of petroleum products by PSUs would increase substantially during this period, whereas the product movement by private companies would remain stable at 4 percent. It may be inferred that on the whole pipelines would continue as the most preferred mode of transportation of petroleum products. Although Railways at present transport a major share of products, their percentage contribution is expected to decline primarily due to expansion of pipelines network. This would ensure balance between the ability of transport to serve economic development and to conserve energy, promote safety and sustain future quality of life.

As Table 5.3 shows, about 20 percent (~105 Mt) of petroleum products will be transported by rail. This is small compared with movement of coal for power (~1460 Mt). Therefore, POL movement has little effect on planning for railways.

Investment Required

Table 5.4 gives a list of proposed product pipelines or those that are already under implementation. The table shows total length of proposed or under implementation product pipelines as 5769 km. Because the length of some of the proposed or under construction pipelines was not available, the actual length is likely to be greater. Conservatively, we estimate the total length of new pipelines to be 6000 km. The cost of laying a product pipeline and creating the associated infrastructure is estimated to be 1.25-1.50 Rs crore per km (MoP&NG note on costs, 2012). Therefore, it is estimated that investment for new product pipelines will be about Rs 7,500 – 9,000 crore. It should be noted that this is a lower limit because the pipelines that have been included are those that are expected to be completed by 2021-22. The additional pipelines that will be required for the decade FY 2022 to FY 2032 will add to the cost.

Table 5.3 Movement of Petroleum Products(Mt)

Year	**PSUs**					**Private Companies**				
	Pipeline	Coastal	Rail	Road	Total	Pipeline	Coastal	Rail	Road	Total
2011-12	56.76(46)	18.51(15)	40.72(33)	7.40(6)	123.39	2.86(4)	60.87(85)	3.58(5)	3.58(5)	71.61
2016-17	90.14(53)	23.81(14)	45.92(27)	10.20(6)	170.08	2.88(3)	81.53(85)	5.76(6)	5.76(6)	95.92
2021-22	118.56(54)	30.74(14)	57.08(26)	13.17(6)	219.55	3.25(3)	87.84(81)	7.59(7)	9.76(9)	108.45
2026-27	157.64(54)	46.71(16)	75.90(26)	14.60(5)	291.92	4.80(4)	88.86(74)	12.01(10)	15.61(13)	120.08
2030-31	203.92(55)	55.61(15)	88.98(24)	18.54(5)	370.76	5.85(4)	103.83(71)	16.09(11)	20.47(14)	146.24

Note: The figures in parenthesis are percentage shares

Source: Ministry of Petroleum and Natural Gas, (2012).

Table 5.4 Proposed or Under Construction Pipelines for Petroleum Products

Pipeline Name	Length (km)	Capacity (Mtpa)	Company
Hook of Tikrikalan Terminal with MJPL	8	3	Indian Oil
Paradip- Sambalpur-Raipur-Ranchi Pipeline	1,068	5	Indian Oil
Branch Pipeline from KSPL, Viramgam to Kandla	231	0.5	Indian Oil
Augmentation of CBPL	-	1	Indian Oil
Kolkata ATF Pipeline	28	0.13	Indian Oil
Guwahati ATF Pipeline	35	0.07	Indian Oil
Hookup of Jasidih with HBPL	-	-	Indian Oil
CBR Trichy product PL	114	0.4	Indian Oil
Branch Pipeline to Motihari and Baitalpur	275		Indian Oil
Paradip-Haldia-Durgapur LPG PL	710	0.85	Indian Oil
Paradip-Vizag-Vijayawada-Hyderabad PL	1,220	3.35	Indian Oil
Koyali-Pune PL	684	3.85	Indian Oil
Extension of Mathura-Tundla PL to Kanpur	280	3.0	Indian Oil
Branch PL from Panipat-Jalandhar PL to Kudd (H.P.)	105	-	Indian Oil
Extension of CTMPL to Irugur	-		Indian Oil
Extension of Koyali-Ratlam PL to Indore and Nagpur	-	-	Indian Oil
Extension of Panipat-Jalandhar PL to Jammu	-		Indian Oil
Branch Pipeline from KSPL to Rajkot	-		Indian Oil
Pipeline from Bina Refinery to Kanpur	NA	NA	BPCL
Expansion of Mumbai-Bijwasan Pipelines	NA	NA	HPCL
Ramanmandi-Bahadurgarh Pipeline (RMBPL)	250	4.7	HPCL
RamanMandi-Bhatinda Pipeline	30	1.37	HPCL
Raman Mandi-Sangrur Ambala Pipeline	190	1.36	HPCL
Bahadurgarh-Tikrikalan Pipeline	14	1.06	HPCL
Rewari-Kanpur Pipeline (RKPL)	437	5.41	HPCL
Awa Salwas Pipeline (ASPL)	90	0.51	HPCL
TOTAL	5,769		

***Source: Ministry of Petroleum and Natural Gas,* (*2012*)**

Imports and Exports of POL

Rapid growth in domestic consumption of petroleum products and refining capacity has increased the country's dependence on imports of crude oil. On the other hand, India has not only become a net exporter of petroleum products, but is now the largest exporter of petroleum products in Asia (MoP&NG, 2011: 139). This section gives an estimate of the imports and exports of crude oil and petroleum products and the resulting liquid bulk traffic at ports.

Table 5.5 provides the details of the calculation. We first estimate the requirements for crude oil which is based on the sum of domestic demand and the net exports of petroleum products. Domestic demand for petroleum products has been estimated for the 12th and 13th Plan by MoP&NG (MoP&NG, 2011: 49-50). We extrapolated the results until 2031-32 using the CAGR for the 13th Plan. While in its report for the 12th Plan, MoP&NG did estimate the exports of petroleum products for the 12th Plan, we could not find any projections for exports beyond 2016-17. Because the level of exports are linked to the global requirements for petroleum products, we have assumed that India's exports of petroleum products would remain at the level projected in 2016-17 by MoP&NG. Global requirements for petroleum products were obtained from International Energy Outlook by the Energy Information Administration (EIA) of the US. Imports of petroleum products which consist mostly of LPG have remained stable at about 11 Mtpa. We have assumed that imports remain at this level throughout the study period.

The total amount of petroleum products that need to be produced in the country is equal to the domestic demand plus net exports. In Table 5.5, this amount is shown as "Total to be Produced." Based on data provided by MoP&NG for the 12th Plan, a tonne of crude oil yields about 0.93 tonnes of petroleum products (MoP&NG, 2011:163). We use this estimate of yield to calculate the requirements for crude oil in the country. By 2031-32, this requirement is estimated to reach 556 Mt. Some of this requirement will be met by domestic production. Recent projections for the 12th Plan Period show a small decline in production over the plan period (PetStats, 2011-12:42). Therefore, we have assumed that domestic production will remain at current levels. Subtracting domestic production from total requirements for crude oil give us the amount of crude oil that needs to be imported. It is expected to reach 515 Mt by 2031-32. The sum of POL imports (crude oil and petroleum products) and exports (petroleum products) is shown in Table 5.5 and is expected to reach 631 Mt by 2031-32. Port traffic includes not just this amount but also some domestic crude that is produced off-shore and crude oil and petroleum products moved by coastal ships. Estimating this amount directly is very difficult. Instead, we looked at POL port traffic for the last several years and compared it with the total imports and exports of POL. We found that the ratio of POL port traffic to POL imports and exports over the last several years has varied between 1.25 to 1.53 with an average of 1.37. We have used the average of 1.37 to arrive at POL port traffic which is shown in the last line of Table 5.5.

Table 5.5 Estimation of POL Traffic at Ports (Mt)

		2011-12	2016-17	2021-22	2026-27	2031-32
1	Domestic Demand for Petroleum Products	147	186	245	322	424
2	Gross Exports of Petroleum Products	58	91	94	100	104
3	Gross Imports of Petroleum Products	10	11	11	11	11
4	Net Exports of Petroleum Products (2-3)	48	80	83	89	93
5	Petroleum Products to be Produced in India (1+4)	195	266	328	412	517
6	Requirements for Crude Oil (5/0.93)	210	286	353	443	556
7	Domestic Production of Crude Oil	38	41	41	41	41
8	Required Imports of Crude Oil (6-7)	172	245	312	401	515
9	Total Imports and Exports of POL (2+3+8)	240	347	417	513	631
10	**Total POL Traffic at Ports (9 x 1.37)**	**329**	**475**	**572**	**702**	**864**

Source: Working Group Research

Natural Gas

Natural Gas constitutes 24 percent of the total energy mix in the World and in comparison, the natural gas share in Indian energy basket occupies around 11 percent during 2010. It is projected that the growth of natural gas demand in India in the next two decades will alter the primary energy mix of India, by way of substitution, from oil to gas and reach upto 20 percent. MoP&NG estimates that gas demand will increase to 473 MMSCMD by 2016-17 and 606 MMSCMD by 2021-22, and would be about 790 MMSCMD by 2031-32 (MoP&NG, 2011a; MoP&NG, 2011b).

The production of natural gas has increased from 89 MMSCMD to 143 MMSCMD at annual growth rate of 17 percent during the period 2007-08 to 2010-11. It is expected that more discoveries of natural gas will take place under NELP in the coming years. Demand for natural gas has increased by 24 percent during this period. Demand for natural gas up to 2031-32 is estimated based on the domestic production estimates as provided by the Directorate General of Hydrocarbons (DGH) and expected demand for natural gas by various sectors viz. Power, Fertilizer, City Gas, Industry, Petro Chemicals/ Refinery/Internal Consumption and Sponge Iron/Steel. It is assumed that from 2017-18 onwards additional gas would be available domestically and CBM Blocks and other future discoveries. Accordingly, a growth rate of 6 percent is assumed from 2017-18 onwards and the availability is expected to stabilize thereafter at an annual growth rate of 3 percent till 2031-32.

The remaining gap in demand is expected to be met through imports using existing facilities at Dahej, Kochi, Dabhol, Hazira and other proposed LNG terminals likely to come up at places like Mangalore, Ennore, Mundra, Paradip etc. Besides, certain Floating Storage Regassification Units (FSRUs) are being planned at port locations like Dighi Port, Mumbai, Paradip, Vizag, Mangalore, Cuddalore Port etc.

The availability of transport infrastructure for gas needs to keep pace with availability of gas and commissioning of user industries. With this objective, the gas transportation needs have been estimated until 2031-32 (including regional and trunk pipelines) as follows:

Table 5.6 Estimates of Demand for Gas

Year	Gas Demand (MMSCMD)
2010-11	170
2011-12	193
2016-17	473
2021-22	606
2026-27	703
2031-32	791

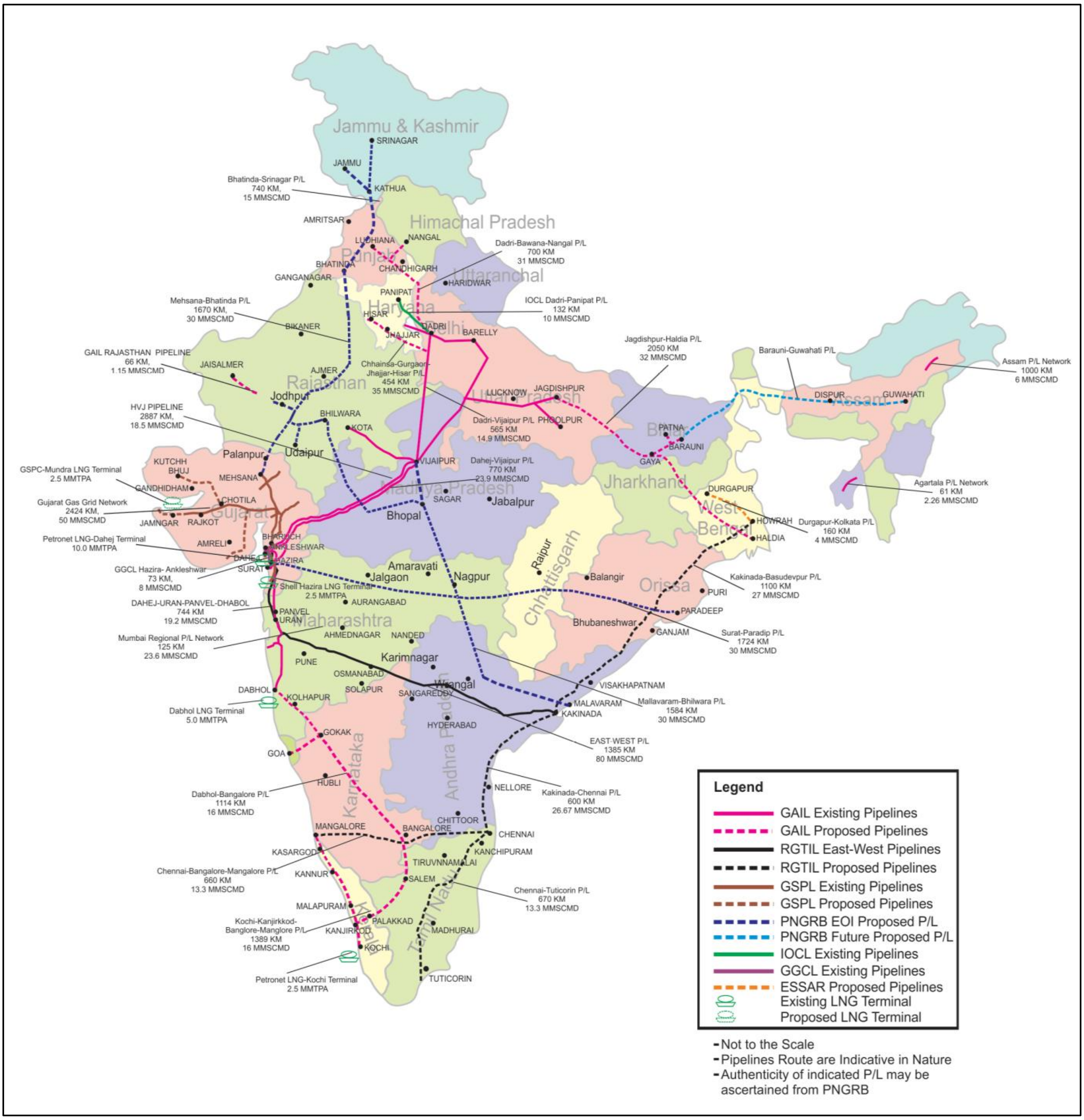
Note: Figures are based on the expectations that IPI/TAPI will be operational from 2018-19 onwards
Source: Ministry of Petroleum and Natural Gas, (2012).

It may be noted that the gas transportation estimates are related to the demand projections for gas that are projected to increase substantially with bulk of the increase in demand projected from sectors like power and fertilizer. According to present trends of domestic availability, demand from other sectors like city gas, industrial, petrochemicals, refineries, internal consumption and sponge iron would be met mostly thorough imported LNG. However, it may be relevant to note that the estimates have not considered the role of price elasticity in relatively price elastic sectors like power and fertilizer. In this scenario, the actual demand could be much lower than the projected.

Pipelines are practically the only mode of inland gas transportation from producing regions to various consumption centres. India presently has approximately 13,000 km of gas Pipelines network with a total design capacity of 334 MMSCMD. As shown in the map in Figure 5.2, this comprises around 8,400 km owned and operated by GAIL, around 1,469 km of East West pipeline operated by RGTIL and remaining pipelines operated by regional players like GSPC, IOCL etc. In view of the growing gas demand and new gas fields along east-coast the need for faster development for gas transportation infrastructure is being emphasized. In 2007, MoP&NG had authorized around 5,771 km of Pipelines to GAIL and 2628 km of pipeline to Reliance Logistics. Besides, GAIL is also upgrading the GREP/DVPL for 1280 km for capacity of 54 MSMCMD.

Further with the PNGRB in place, 4,325 km of pipeline has been authorised by PNGRB through transparent bidding process. In addition to above mentioned pipelines 2,675 km of pipeline is under various stages of bidding by PNGRB.

Figure 5.2 Existing and Proposed Natural Gas Pipelines



Source: Ministry of Petroleum and Natural Gas, (2012)

Table 5.7 summarizes the composition of the pipeline-grid for gas. As can be seen it is expected that the total capacity will be about 1,176 MMSCMD which will meet the requirements given in Table 5.6.

Table 5.7 Expected Composition of Gas Grid at End of 13th Plan (2021-22)

Pipeline Type	Length (km)	Capacity (MMSCMD)	Comments
Existing	13,508	334	Existing
Under Execution by GAIL/RGTIL	9,679	263	12th Plan
Under upgradation by GSPL	1,220	30	12th Plan
PNGRB Bidding Rounds	7,000	243	12th Plan
AGCL/ OIL	350	6	12th Plan
New Greenfield pipelines	4,000	150	13th Plan
Additional pipelines through augmentation	5,000	150	13th Plan
Additional pipelines through spurlines	4,500	0	13th Plan
TOTAL	45,257	1,176	

Source: Ministry of Petroleum and Natural Gas, (2012)

As the table above shows, additional pipelines of about 32,000 km will need to be constructed. It is difficult to estimate the cost of these additional pipelines because the cost per km varies by a factor of 4-5 depending on the diameter of the pipeline and by a factor of more than two depending on the region. It should be noted that some of these new pipelines are already under construction.

Summary of the Petroleum and Natural Gas Sector

Pipelines because of their economic advantage are the main mode of transport for petroleum and natural gas, although other modes are used to a limited extent. For example. private oil companies with refineries on the coast transport crude oil using coastal shipping. Some petroleum products are transported by rail, but the amounts even by 2031-32 (~105 Mtpa)are expected to be much smaller than the transport of coal, expected to be over 1,400 Mtpa. Expansion of pipeline capacity is being carried out. For natural gas, where transport requirements are expected to be about 790 MMSCMD by 2031-32, by the end of the 13th Five Year Plan (2021-22) the pipeline capacity is expected to reach 1,175 MMSCMD indicating the pipeline network will be able to support the transport requirements for natural gas. Thus we see that the petroleum and natural gas sector is not expected to have much of an effect on the surface transport system.

However, this sector is going to have a huge impact on the requirements at ports. Total port traffic for POL is expected to reach 860 Mt by 2031-32. This volume is larger than the expected combined port traffic for thermal and coking coal (about 600 Mt).

Steel Industry

As we discuss later, production of one tonne of steel requires 3-4 tonnes of raw materials. Therefore, in order to estimate the transport requirements for the steel industry, we first estimate the raw material requirements.

The calculations of raw material requirements have been projected on the basis of current norms of consumption and expected improvements in efficiency of operation. Specifically, it has been assumed that (Ministry of Steel, 2012a):

- Iron consumption of 1.6 tonne per tonne of crude steel (CS), based on BF/BOF tech
- Coking coal expected to decrease from 0.8 tonnes per tonne of crude steel to 0.75 tonnes, with increasing use of pulverized coal injection (PCI) and increasing use of scrap in electric furnaces. (Use of scrap expected to increase from 15 percent in 2016-17 to 25 percent in 2031-32.)

With all these improvements in efficiency it is expected that the total of all input materials required to produce one tonne of crude steel will decrease to 3 tonnes from the current level of 4 tonnes. Naturally, these improvements will reduce the need for transportation of raw materials.

Based on these requirements, the amount of raw materials to be transported for the terminal year for each of the next four plans has been estimated in the following table. Annex III. 5.3 gives the details of the calculations.

Table 5.8 Estimates of Amounts of Raw Materials and Steel to be transported

(All quantities are in Mt)

	Material	2016-17	2021-22	2026-27	2031-32
1.	Iron Ore	217	346	526	736
2.	Coking Coal	86	135	203	280
3.	PCI	11	17	41	56
4.	Non-coking Coal	39	67	82	122
5.	Scrap	15	36	78	145
6.	Others	118	188	284	398
7.	**Total Steel Making Raw Materials(1+2+3+4+5+6)**	**486**	**790**	**1,213**	**1,737**
8.	Total Finished Steel	113	199	325	495
9.	**Total Raw Material and Finished Steel (7+8)**	**599**	**989**	**1,538**	**2,232**

Source: Ministry of Steel (2012a)

These transport requirements do not include the transport requirements for exporting iron ore. While these exports are and have been quite large (~50 percent of iron ore mined), they have declined recently because of the ban on export of iron ore. Further, it is expected that because the iron ore resource will need to be conserved to ensure availability of adequate amount of steel for the country's development, the exports will continue to decrease and will not be significant after 2016-17.

Steel production in 2011-12 was 73 Mt (provisional estimate) (MoS website, An Overview of Steel Sector, accessed January 7, 2013). Assuming the same ratio of material to be moved to finished steel production as for 2016-17, the total raw material and steel that was moved in 2011-12 was about 390 Mt. As Table 5.8 shows, this amount is projected to increase to 2232 Mt in 2031-32; almost a six-fold increase over the next twenty years.

Currently most of the material for large steel plants is moved by rail while for small and medium units, road is the preferred mode of transport. We have assumed this pattern remains throughout the study period. The attached Table 5.9 gives the details of the modal distribution of traffic

Table 5.9 Modal Distribution of Raw material Traffic between Road and Rail

	Rail		Road	
	Raw Materials	Finished Steel	Raw Materials	Finished Steel
Mega/Large Projects	90%	70%	10%	30%
Small & Medium Units	30%	30%	70%	70%

Source: Ministry of Steel (2012a)

Current lead distances for raw materials and finished steel are shown in the following Table 5.10. While lead distances for iron ore are short reflecting the proximity of steel plants to iron ore mines, the lead distances for finished steel are large (~1000 km) because finished steel is transported across the country. Consequently the transport requirements for finished steel in tonne-km are much higher than for raw materials. Using these numbers for lead distances, projected rail traffic for the steel industry is shown in the Table 5.11.

Table 5.10 Average Lead Distances for Steel and Raw Materials (km)

Iron Ore	Coal	Other Raw Materials	Pig Iron and Finished Steel
325	405	763	988

Source: Ministry of Steel (2012a)

Table 5.11 Estimated Railway Traffic Due to the Steel Sector

	TOTAL INDIA	2016-17		2021-22		2026-27		2031-32	
		Mt	Mt-km	Mt	Mt-km	Mt	Mt-km	Mt	Mt-km
1	Iron Ore	164	53,320	262	85,142	398	129,354	557	180,978
2	Coking Coal	65	26,330	102	41,260	154	62,168	212	85,721
3	PCI	8	3,291	13	5,157	31	12,434	42	17,144
4	Non-coking Coal	30	12,062	51	20,633	62	24,998	92	37,323
5	Scrap	11	10,804	27	26,965	59	58,080	110	108,392
6	Others	89	68,102	143	108,736	213	162,476	301	229,663
7	Total Steel Making Raw Materials (1+2+3+4+5+6)	367	173,908	597	287,895	916	449,509	1314	659,222
8	Total Finished Steel	68	67,463	120	118,806	196	194,030	299	295,522

Source: Ministry of Steel (2012a)

We have also estimated the road traffic for the steel sector and it is shown in the Table 5.12. As expected, road traffic is much less than rail.

Table 5.12 Estimated Road Traffic Due to the Steel Sector (Mt)

	TOTAL INDIA	2016-17	2021-22	2026-27	2031-32
1	Iron Ore	53	84	128	179
2	Coking Coal	21	33	49	68
3	PCI	3	4	10	14
4	Non-coking Coal	10	16	20	30
5	Scrap	4	9	19	35
6	Others	29	46	69	97
7	Total Steel Making Raw Materials (1+2+3+4+5+6)	118	192	295	423
8	Total Finished Steel	45	79	128	196
9	Total Raw Materials and Steel (7+8)	163	271	424	619

Source: Ministry of Steel, (2012a)

Imports of Coking Coal

As mentioned in Chapter 2, much of the coking coal reserves in the country have high ash content rendering them unsuitable for steel-making, consequently, the steel industry relies heavily on imports of coking coal. Currently, about 70 percent of the coking coal required by the steel industry is imported. Because the domestic production of coking coal is expected to remain stagnant or may even decline, the share of imports of coal is expected to increase to 75, 80 and 85 percent in 2016-17, 2021-22 and 2026-27 respectively, and to remain at that level for the rest of the study period (MoS, 2012). Using these assumptions, the imports of coking coal for the steel industry have been estimated and are given in Table 5.13.

Table 5.13 Imports of Coking Coal for Steel Industry by State (Mt)

	2011-12	2016-17	2021-22	2026-27	2031-32
Odisha	7.8	15.8	26.4	42.2	58.2
Chattisgarh	4.2	8.5	14.1	22.6	31.2
Jharkhand	4.5	9.2	15.3	24.6	33.9
West Bengal	2.2	4.4	7.4	11.9	16.4
Karnataka	2.9	5.8	9.7	15.5	21.4
Tamil Nadu	1.0	2.1	3.5	5.5	7.6
Maharashtra	1.7	3.5	5.9	9.5	13.1
Andhra Pradesh	2.0	4.1	6.8	10.9	15.0
Gujarat	2.4	4.9	8.2	13.1	18.1
Other Locations	3.1	6.2	10.4	16.7	23.0
Total India	31.8	64.5	107.7	172.5	237.8

***Source: Ministry of Steel*, (2012a)**

Summary of the Iron and Steel Industry

The transport requirements of the steel industry are going to have a large impact on the transportation system for two reasons: (1) one tonne of steel requires 3-4 tonnes of raw materials; and (2) the intensity of steel use in the economy is expected to increase so the requirements for steel will grow faster than the GDP. The total quantity of material that will need to be transported for the steel industry is expected to reach 2200 Mt by 2031-32; a six-fold increase from 2011-12.

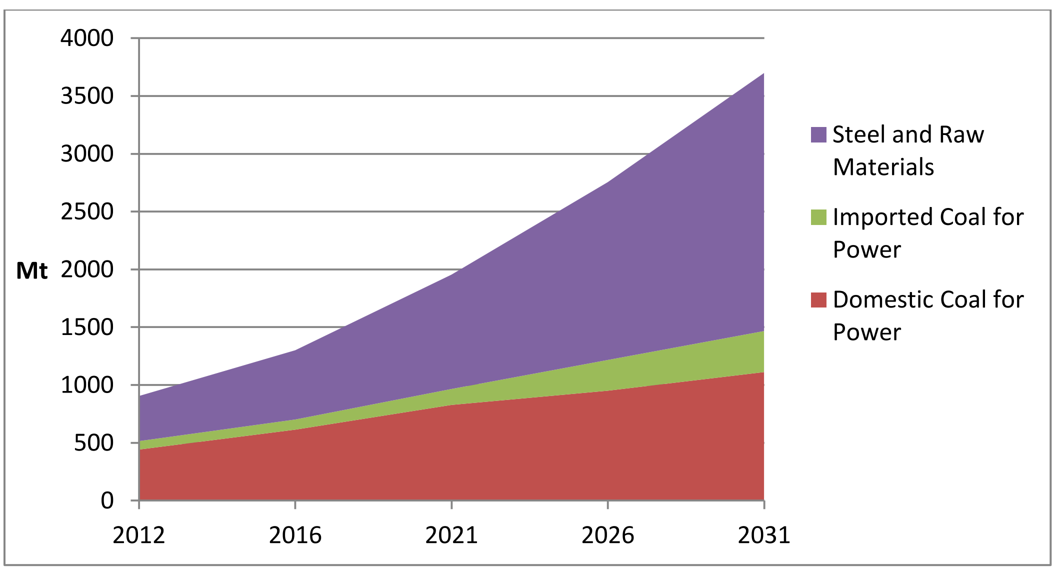
The main impact on the transport network is expected to come from the transport of iron ore and coking coal. Most of the major steel plants are located and are expected to continue to be located near iron ore mines. So while the amount of iron ore to be transported will be large, the distances will not be large and will use short rail routes. About 85 percent of the coking coal for the industry will be imported, and hence the requirements at ports will increase. Coking coal imports are expected to reach 240 Mtpa by 2031-32.

Chapter 6. Infrastructure Requirements and Investment Planning for Railways

Introduction

As seen from the previous chapters, India's requirements for bulk commodities are expected to grow rapidly over the next two decades. For the power sector, coal will remain the dominant fuel even though its share is expected to decrease marginally. The use of domestic coal for the power industry will be limited by the amount that will be produced and is expected to grow by about 2.5 times. Imports of coal for the power sector however, will grow much faster; by almost 5 times by 2031. Because the intensity of steel in the economy is expected to increase, steel requirements will grow faster than the growth of the economy. Current projections are that requirements for steel will grow by almost seven times the current level. Keeping in mind that a tonne of finished steel requires 3-4 tonnes of raw materials, the transport requirements for steel industry will be huge. Figure 6.1 shows the transport requirements for moving coal for the power industry and steel and its raw materials. The transport requirements for the power and steel industry are expected to grow from about 900 Mt now to 3700 Mt in 2031-32.

Figure 6.1 Amount of Bulk Materials to be Transported for Power and Steel Industries



Source: Working Group Research

Railways is the one of the main mode of transport for dry bulk commodities. The rail network is already stretched to capacity with almost all the major trunk routes bearing traffic well above their design capacity. This chapter assesses the additional requirements for transport of bulk commodities that will be imposed on the rail network and the upgradation of the network that will be required.

Transport of coal and iron-ore by rail can be broadly broken up into five segments:

1. **First Mile Connectivity** where coal/iron-ore is transported from the mine to the rail siding.
2. **Feeder Routes at the Source End** which carry the coal/iron-ore from the rail siding to the trunk route
3. **Trunk Routes** which carry the material long distances usually between states.
4. **Feeder Routes at the Destination** which move the material from trunk route connection point to the rail siding at the destination power or steel plant.
5. **Last Mile Connectivity** where the material is moved from the rail siding to the power or steel plant.

It is important to ensure that each link in the transport chain from mine to power/steel plant functions effectively because the overall transport chain will be only as effective as its weakest link. In that spirit, in this chapter we consider all segments of the rail transport chain. Of course, not all coal or iron ore shipments will traverse all five segments. For example, coal for power plants within a coal-producing state may be carried by a single feeder route that connects the rail siding at the mine to the power plant. First and last mile connectivity are not usually provided by rail but we have included them in this chapter because they are important in ensuring that coal or iron ore moves in an efficient and effective way. As we shall see later, poor first and last mile connectivity can be a bottleneck in the transport of bulk material and deserves attention.

We begin by looking at the pattern of movement of bulk commodities for the power and steel industry based on the work in the last two chapters. Then the requirements for each part of the rail network are discussed: (1) trunk rail routes; (2) feeder routes at source; (3) feeder routes at destination; (4) first mile connectivity; and (5) last mile connectivity. We follow this with a discussion of two issues related to Railways' performance : (1) build-up of pithead coal stocks; (2) rail efficiency and technology improvement. We end the chapter with a priority list of the required upgradation and augmentation of the rail network and a rough plan-wise estimate of the associated investment.

Pattern of Movement of Bulk Commodities for the Power and Steel Industry

Movement of Coal for the Power Industry

As mentioned above, not all shipments of coal will traverse all the five types of segments identified in the itemized list. Because the transport requirements can be quite different depending on the types of rail segments traversed, it will be useful to divide transport of domestic coal for the power sector into three categories:

1. Transport within the coal-producing states which relies mostly on road transport, MGR, conveyor belts/ropes and short rail routes.
2. Transport to states neighboring coal-producing states which takes place either on non-DFC routes or on short sections of high density trunk routes that will later be covered by dedicated freight corridors (DFCs).
3. Transport to distant states which makes extensive use of high density trunk routes that will later be covered by DFCs.

Using the outputs of the model described in Chapter 4, Table 6.1 shows the amount of domestic coal that is likely to be transported in each of these categories for the three scenarios.[4] It should be noted that the share of in-state consumption which is already at 44 percent is expected to increase to 60 percent by 2031-32 in the base case. In the low case in 2031-32, it is slightly lower at 54 percent and in the high case it is higher at 62 percent. If we include transport to neighboring states to get an estimate of the share of transport within the coal producing regions, we find that the share of these categories grows to 64-73 percent by 2031-32. These trends are consistent with the finding in Chapter 4 that as the economy grows, domestic coal is used "closer to home." While in some cases, the regional or in-state movement may indeed be on a short part of a DFC, **it can be seen that a very large portion of domestic coal will not make extensive use of DFCs**.

This finding is reinforced by an analysis of how much coal is transported by the various modes. A report by PwC states that the share of rail is about 49 percent, MGR is 19 percent and road is about 26 percent (PwC, 2009) (See Figure 6.2 below).

[4] These estimates are indicative. Specifying an exact route for transport of coal would require a precise origin and destination. Because the modeling exercise in Chapter 4 treated an entire state as a node, such precise identification of origins and destinations was not possible in this study. A much more detailed modeling exercise with a much higher resolution for locating power plants would be required, which was not possible for this study.

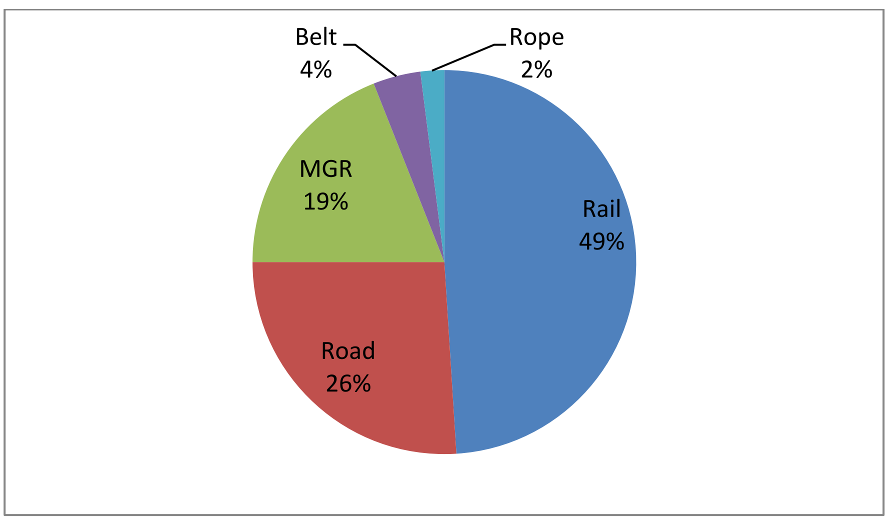
Table 6.1 Movement of Domestic Coal (All quantities are in Mt)

Year	Consumption within Supply States	Consumption in Neighboring States	Long-Distance Transport – (Extensive Use of DFCs)	Total	Share of In-State Consumption	Share of In-State Consumption and Neighboring States
Base Case						
2011-12	194	64	156	442	44%	58%
2021-22	429	152	212	828	52%	70%
2031-32	664	110	260	1112	60%	70%
Low Case						
2011-12	194	64	156	442	44%	58%
2021-22	396	140	222	828	48%	65%
2031-32	602	114	288	1112	54%	64%
High Case						
2011-12	194	64	156	442	44%	58%
2021-22	443	150	184	828	54%	72%
2031-32	693	117	222	1112	62%	73%

Note: For transport to neighboring states and for long-distance transport, only the major coal consuming states were considered. Therefore, the total in column 5 will be slightly higher than the sum of columns 2, 3 and 4.

Source: Working Group Research (Model Outputs)

Figure 6.2 Share of Different Modes for Transport of Domestic Coal



Source: Price Waterhouse Coopers, (2009)

A similar pattern emerges when we examine the movement of imported coal. As can be seen from Table 6.2, the share of consumption by the coastal states reaches over 80 percent in 2031-32 for the base and high case. It is slightly lower at 71 percent for the low case. In such a scenario where most of the imported coal is expected to be used close to the coast, short rail routes or conveyor belts are likely to be important.

Table 6.2 Movement of Imported Coal

All quantities are in Mt

Year	Consumption within Coastal States	On Non-DFC Routes	Long-Distance Transport – Extensive Use of DFCs	Total	Share of Coastal States Consumption
Base Case					
2011-12	53	0	14	73	73%
2021-22	119	0	19	138	86%
2031-32	293	0	59	355	82%
Low Case					
2011-12	50	0	8	61	83%
2021-22	26	0	1	27	96%
2031-32	43	0	18	61	71%
High Case					
2011-12	54	0	15	76	72%
2021-22	131	0	25	158	83%
2031-32	382	0	75	460	83%

Note: For the routes covered by DFCs and non-DFC routes, only states which consumed more than 3 Mtpa of imported coal were considered. Therefore, the total in column 5 will be slightly higher than the sum of columns 2, 3 and 4.

Source: Working Group Research (Model Outputs)

Thus we see that a progressively greater share of coal will be used within the source and coastal states, and it can be expected that the share of shorter rail routes, road, MGR and belts/ropes will grow. Clearly, attention must be focused on these modes of transporting coal.

Movement of Bulk Materials for the Steel Industry

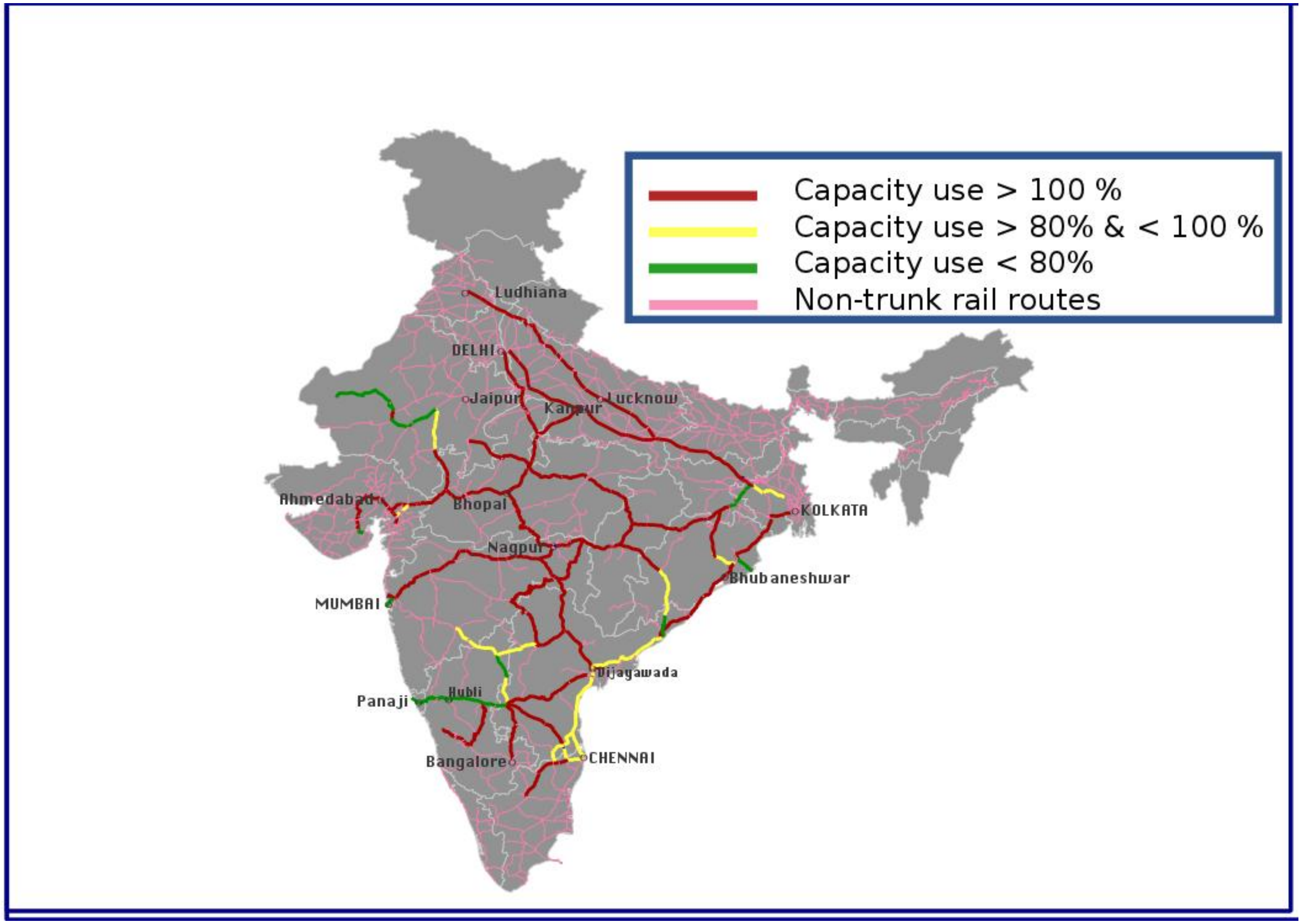
The steel industry requires transport of iron ore, coking coal, non-coking coal, other raw materials such as limestone, and finished steel. As discussed in Chapter 5, lead distances for non-coking coal and iron ore are short because of proximity of steel plants to iron ore and coal mines. Consequently much of the movement of iron ore and non-coking coal is on short rail routes for large steel plants and by road for the smaller plants. Similarly, because of the proximity of the ports which receive coking coal imports, the lead distances for imported coking coal are short and transport is on short rail routes for large steel plants and by road for smaller steel plants. Finished steel is transported across the country and its effect on the transport network is diffused throughout the network, and therefore its effect on specific routes is likely to be not so significant and we do not cover it here.

Trunk Railway Routes

Status of Rail Routes

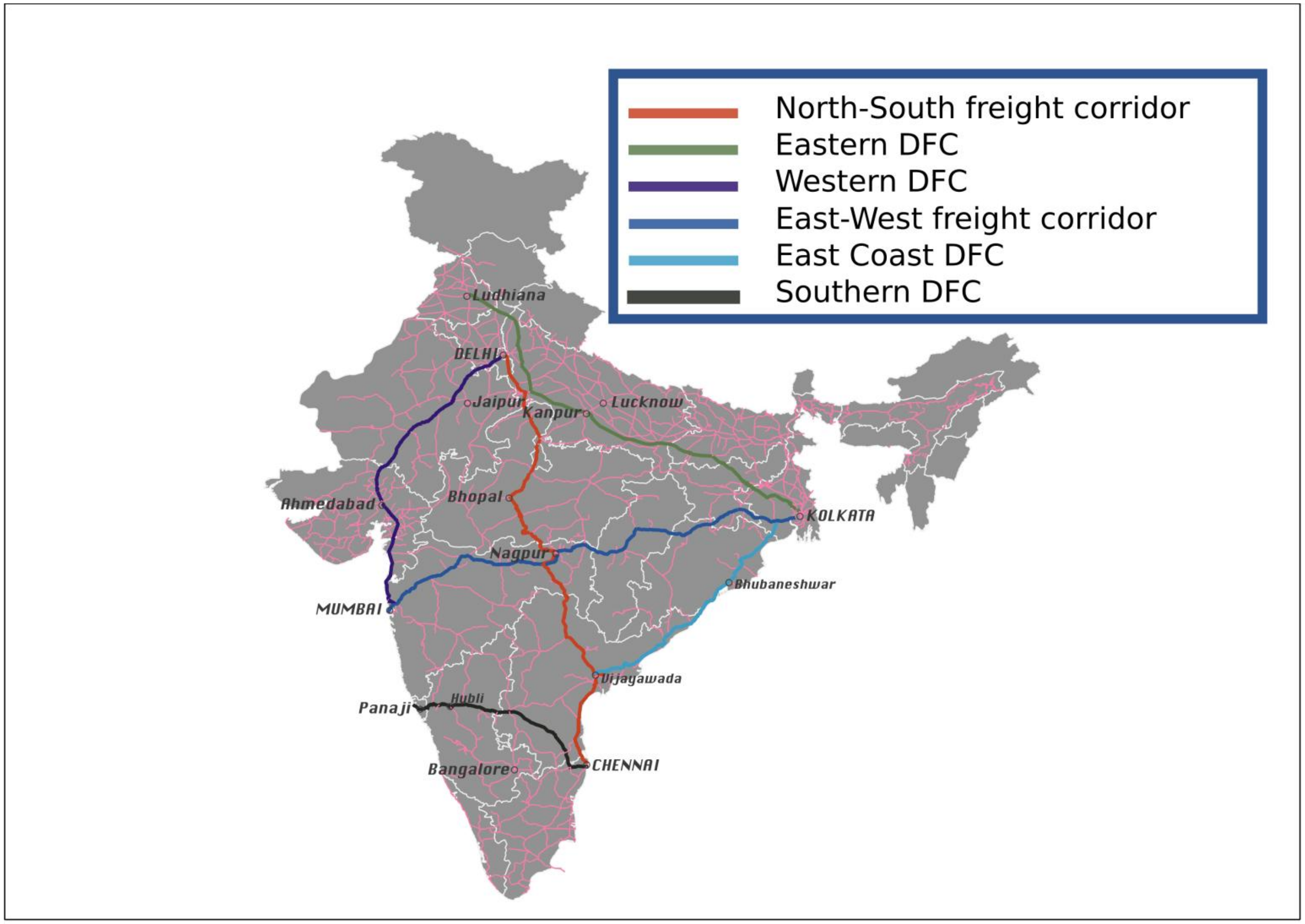
Figure 6.3 shows the main rail routes over which coal, iron ore, iron, steel, limestone and dolomite are transported. These routes cover more than 80 percent of these commodities transported by rail. We also examined the level of capacity utilization for the sections of the routes. Generally, a section is said to have reached saturation if the capacity utilization is greater than 80 percent. Therefore, we have divided the sections that comprise these routes into three categories: (1) where the capacity utilization is less than 80 percent (green); (2) where the capacity utilization is between 80 percent and 100 percent (yellow); and (3) where the capacity utilization is greater than 100 percent (red).

Figure 6.3 Major Routes for Transport of Bulk Commodities



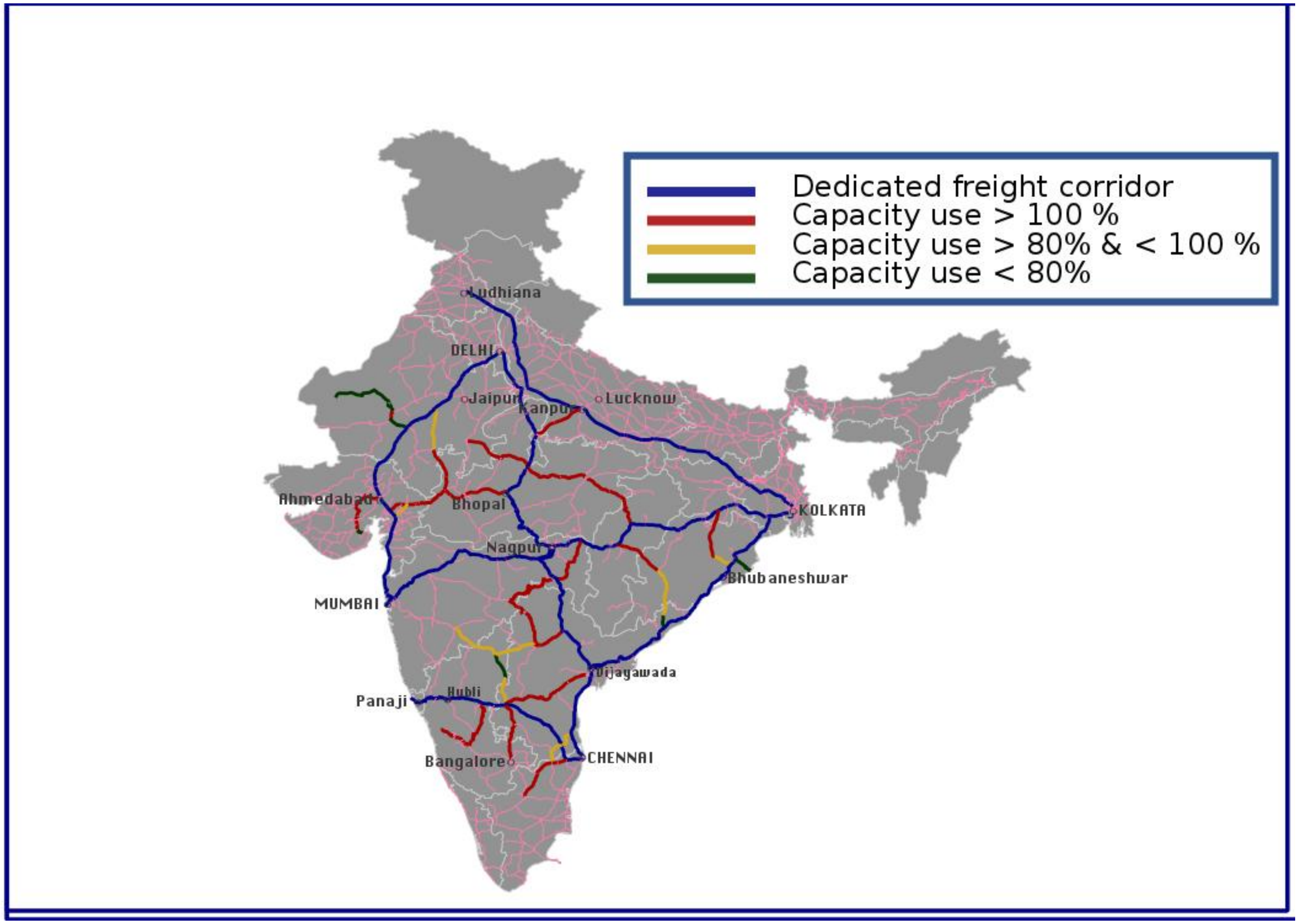
Source: RITES and Working Group Research

Figure 6.4 DFC Routes



Source: RITES and Working Group Research

Figure 6.5 Impact of DFCs on Trunk Routes



Source: RITES and Working Group Research

Almost all the sections on the map in Figure 6.3 are red, implying that almost all sections on the major routes have not only reached saturation, but are operating at a capacity utilization greater than 100 percent, and therefore, almost all the bulk commodity routes face major delays due to congestion. This is particularly relevant for transport of coal over long distances which would make extensive use of the high density network. It is also relevant for transport within coal bearing states and to neighboring states to the extent that some of this transport may occur over short sections of these trunk routes.

Indian Railways Plans for High Density Corridors

Indian Railways recognized the problem several years back and has proposed construction of dedicated freight corridors (DFCs). Six DFCs totaling 9,538 kms have been proposed:

(a) Western DFC (Delhi-Mumbai) 1,534 kms.
(b) Eastern DFC (Ludhiana-Kolkata) 1,839 kms.
(c) East West DFC (Howrah-Mumbai) 1,976 kms.
(d) East-Coast DFC (Kharagpur-Vijaywada) 1,097 kms.
(e) South DFC (Chennai –Goa) 902kms.
(f) North South DFC (Delhi-Chennai) 2,190 kms.

Of these the first two are already under construction and prefeasibility studies have been carried out for the others. Figure 6.4 shows the six DFCs. Figure 6.5 shows the impact of the DFCs on the trunk routes for transport of bulk commodities. While many of the sections will no longer be congested (blue), there will still be some sections shown in red and yellow that will be congested and will require augmentation of their capacity.

Schedule for DFCs

The Western DFC and Eastern DFC are under construction and scheduled to be completed by 2017. The other four DFCs have been proposed and not yet approved and the earliest that they would be completed is 2023.

As we mentioned earlier, transport of coal between distant states will make extensive use of DFCs. Transport within coal bearing states and to neighboring states may make use of short sections of DFCs but will mostly use shorter feeder routes and non-rail modes of transport. In order to understand the pattern of movement of coal that will make extensive use of DFCs, Table 6.3 shows the approximate volumes of domestic and imported coal that are likely to be transported over long distances on DFCs. Movement of coking coal is not included because most of that movement occurs within iron-ore rich states as discussed in Chapter 5.

Table 6.3 Expected Long Distance Movement of Domestic and Imported Coal on DFCs for the Power Sector (Mt)

Year	Eastern	Western	East-West	North-South	East Coast	Southern	Total - On Routes Covered by DFCs
Base Case							
2012	88	6	23	30	22	0	170
2021	124	14	57	23	13	0	231
2031	211	30	30	33	15	0	319
Low Case							
2012	88	6	23	30	22	0	170
2021	99	1	62	36	25	0	223
2031	207	9	78	0	12	0	306
High Case							
2012	88	6	24	30	22	0	171
2021	105	18	60	23	3	0	209
2031	212	31	37	8	8	0	297

Source: Working Group Research

As Table 6.3 shows, an overwhelming portion of long distance movement of coal will take place on the Eastern DFC. In the next decade about half the long-distance transport of coal will take place on it; by 2031-32 the share is expected to increase to two-thirds. The Western DFC will carry imported coal mostly from Gujarat to the northern and north-western states. The East-West, East-Coast and North-South DFCs will carry about the same amount of coal as each other but much less than the Eastern DFC. The Southern DFC is expected to carry almost no coal.

Therefore, for long distance transport of coal the Eastern DFC is far more important than the others and it should be given the highest priority. In addition, the traffic on the Eastern DFC will be highest closest to the coal-fields and will decrease as coal is unloaded at successive states on the route to the furthest state. For example, the eastern end of the Eastern DFC is likely to carry coal destined for several states: Bihar, UP, Delhi, Haryana and Punjab, but by the time it gets to the western part of the country it will be carrying coal only for Haryana and Punjab, the rest of the coal having been unloaded en-route in Bihar, UP and Delhi. This importance of the eastern end would also apply to the other DFCs for similar reasons. Another reason for focusing on the eastern end of the DFCs is that transport of coal within coal producing states and to neighboring states is likely to use sections of DFCs that are short but the volume of traffic is likely to be high. Almost all this use of short sections of DFCs will occur in the eastern part of the country.

Another issue related to construction of DFCs is that given the size of the DFC projects and associated challenges, it is possible that the DFCs may be delayed, particularly the remaining four for which approval is yet to be obtained. Given the time it will take to make the DFCs operational even if there are no delays, the traffic will grow and some short-term augmentation will be required; otherwise, the existing infrastructure will be strained to the breaking point. This situation doubles the challenge because not only must long term measures be initiated, but short term measures are also needed. Given limited resources, creative solutions will need to be found to ensure that there is no unnecessary duplication of efforts and expenditure. Furthermore, it should be ensured that the augmentation required between now and when the DFCs are completed does not result in duplication of investment. It could be that the augmentation will support increase in passenger traffic on these corridors once freight shifts to the DFCs.

Rail Feeder Routes at Mines and Plants

Feeder routes are critically important for the effectiveness of the bulk transport system, particularly at the source end, because they bring the material (coal or iron ore) up to the trunk route that then carries it to its destination. All the coal and iron-ore bearing rail traffic has to be transported on these feeder routes. Therefore, inadequate transport capacity on these routes will have wide repercussions for the power and steel industry.

Feeder routes at the destination end bring the material from the trunk route to the destination plant. Generally, feeder routes at the destination side are not much of a problem because the transportation capacity required for a single plant is quite low. However, power plants in coal producing states are likely to come up in clusters of about 4000 MW at locations not yet known, and are likely to require new rail lines directly from mines to the power plants. Attention will need to be paid to these routes too.

In the case of coal, most of the increase in coal production is expected to come from three regions: (1) Talcher and Ib Valley coalfields in Odisha with a potential increase of 110 Mtpa by 2031-32; (2) North Karanpura coalfields in Jharkhand with a potential increase of 75 Mtpa; and (3) Mand-Raigad coalfields in Chhattisgarh with a potential increase of 90 Mtpa. Table 6.4 gives a list of the critical routes in these areas. Early implementation and completion of these rail connectivity projects is important if the need for domestic coal for power is to be met in the coming two decades. As the table shows, some action has been taken by the Railways on several of these projects but much more needs to be done.

Table 6.4 Critical Feeder Routes for Coal

No.	Rail Link	Distance (km)	Cost (crore Rs)	Date Started	Initial Projected End-Date
1	North Karanpura Coalfield – JH, Tori-Shivpur-Hazaribagh, New BG line	92	621	2000	31.12.2012
2	North Karanpura Coalfield – JH, McClouskiganj-Piparwar New BG line	30.5	142	1990	Sep-11
3	Mand-Raigarh Coalfields – CH, Bhupdeopur-Baroud-Durgapur	91	310	Approved	March 2018
4	Ib Valley Coalfield – Odisha, Barpali-Jharsuguda-Gopalpur- Manoharpur Tract	52.4	470	2006	31.03.2012
5	Talcher Coalfield – Odisha, Jarpada-Angul - Talcher Rail Corridor	87	To be estimated	To be approved	NA
6	Talcher Coalfield – Odisha, Radhikapur West Block – Angul Rail Corridor	50	To be estimated	To be approved	NA
7	Talcher Coalfield – Odisha, Talcher – Dhamra Port via Bhadrak[5]	150	To be estimated	To be approved	NA
8	Singareni Coalfield – AP, Bhadrachalan Rd - Sattupalli	52	360	To be done on PPP basis	NA
	TOTAL	605	3510		

Note: For the purpose of calculating total costs, for routes where costs are yet to be estimated, it was assumed that the cost would be the the average cost of the other routes in Rs crore/km.

Source: Ministry of Coal, (2012)

For example, the project to construct a new broad gauge line for the North Karanpura coalfield from McClouskiganj to Piparwar was started way back in 1990. IRCON was awarded the contract but it left the job in 2002. Another five years went by before RITES was hired in to complete the work. While the new completion date was September 2011, the work has still not been completed. The Tori-Shivpur-Hazaribagh line, also in North Karanpura coalfield, was started in 2000 and had a scheduled completion date of end of 2012 but only 41 crores of the Rs 148 crores payment made to the Railways has been utilized. The 40 km single line rail corridor between Angul and Talcher is mostly complete but has been held up because of land acquisition issues for a 4 km stretch. On the other hand, there are several projects such as the extension of

[5] Angul-Sukinde new line has been sanctioned. Sukinde-Bhadrak line exists but if a new line is required, then approval will be needed.

the double line between Bhupdeopur-Baroud-Bijari – Durgapur which have not even been started. For some of them even cost estimates have yet to be made.

As Table 6.4 shows, the combined length of these links is about 600 km and the total cost is expected to be about Rs 3500 crore. The Railway Plan for the 12th Plan has been tentatively estimated at Rs 5.19 lakh crores (Bansal, 2013). The amount required for these critical feeder routes for coal is about 0.7 percent of the total Railway Plan. Given that these links are essential for the transport of the most of the additional coal that is going to be produced in the coming two decades and the relatively low investment required, these links must be given top priority and be completed within this Plan.

For the iron and steel industry too there are several rail connectivity or capacity augmentation projects that are awaiting completion and these are listed in Table 6.5. Iron ore is transported from the iron ore region of Barajamda, Barbil and Banaspani In Odisha to steel plants. Several of the projects for new lines and doubling in Table 6.5 such as Banaspani-Daitar and Angul-Sukinda have been inititated to facilitate this transport of iron ore (MoS, 2012).

As Table 6.5 shows, the combined length of these links is about 2340 km and the total cost is expected to be about Rs 11,740 crore. This amount is about 1.7 percent of the total Railway Plan for the 12th Plan. As with the critical feeder routes for coal, these links are essential for the transport of iron ore, these links must be given top priority and be completed within this Plan for the unhindered growth of the iron and steel industry.

The major reasons for the delays in providing these links are (MoS, 2012:15):

- Difficulties in acquiring land and delays in clearances
- Projects are initiated only if they meet stringent requirements of guaranteed minimum traffic to enable Railways to earn a minimum return on its investments. Private participation by steel plant owners may be one way to solve this problem. We discuss this at greater length later in this chapter.
- Rail projects have a long gestation period and more advance planning needs to be done so that railway infrastructure grows as there is economic growth in the region.

These critical feeder routes should be completed as soon as possible. Further, these routes should be designed to handle 25-30 tonne axle load to permit so that the capacity of the lines is effectively increased.

Table 6.5 Critical Feeder Routes for the Iron and Steel Industry

State	Name of the Project	Km	Cost in Rs. Cr. (2011-12)
	NEW LINE		
Odisha	Angul-Sukinda Road (Suppl.)	99	639
Jharkhand	Hansdiha-Godda	30	267
Andhra Pradesh	Bhadrachalam Road-Sattupalli	56	338
Chattisgarh	Dallirajahara-Jagdalpur	235	1105
Tamil Nadu	Attipattu-Puttur	88	447
Karnataka	Kottur-Harihar via Harpanhalli	65	354
Karnataka	Hubli-Ankola (Suppl.)	167	338
DOUBLING			
Odisha	Sambalpur-Titlagarh	182	951
Odisha	Sambalpur-Talcher	174	679
Odisha	Banspani-Daitari-Tomka-Jakhapura (Suppl.)	180	943
Odisha	Barbil- Barajamda	10	52.5
Odisha	Bimalgarh- Dumitra	18.3	115.66
Odisha	Banspani-Jaruri	09	90.88
Odisha	Champajharan- Bimalgarh	21	151.09
Odisha	Brundamal-Jharsuguda flyover connection to join DN Line (Suppl.)	-	88
Andhra Pradesh	Vizianagram-Kottavalasa 3rd line	35	195
Chattisgarh	Sailari-Urkura	25	73
Chattisgarh	Kirandul-Jagdalpur	150	827
	Raipur-Titlagarh incl. NL Mandi Hasaud-Naya Raipur(20 km) and new MM for conversion of Raipur(Kendri)-Dhamtari&Abhnapur-Rajim branch line(67.20 km)	270	692
Maharashtra	Chandrapura-Rajabera-Chandrapura-Bhandaridah	11	35
Bihar	Kajra-Kiul (Suppl.)	16	48

Jharkhand	Barharwa-Tinpahar	17	75
Jharkhand	Rajkharsawan- Sini- 3rd line	15	91.61
Jharkhand	Sini- Adityapur 3rd line	22.5	95.29
Jharkhand	Bhojudih- Mohuda	23	134.19
Jharkhand	Goelkera- Manoharpur 3rd line (Chakradhpur- Bondamunda Section)	40	271.69
Jharkhand	Dongaposi- Rajkharsawan 3rd line (Suppl.)	75	309.44
Jharkhand	Tinpahar-Sahibganj as PH-I of doubling of Tinpahar-Bhagalpur	38	168
Jharkhand	Sahibganj-Pirpaniti	11	130
Jharkhand	Padapahar- Banspani	32	155.28
West Bengal	Rajgoda - Tamluk - Phase- II of Panskura- Haldia Doubling	13.5	86.91
West Bengal	Panskura - Kharagpur 3rd line (44.7km) with new MM Panskura - Ghatal(32.8 km) NL 11-12	77.5	529.23
West Bengal	Chinpai-Sainthia, Prantik-Siuri	32	596
West Bengal	Gokulpur- Midnapur New Bridge on diversion alignment with substructure & steel super structure on Bridge No,143	2	52.14
Chattisgarh	Salkar Road-Khongsara Patch Doubling	26	143.87
Chattisgarh	Khodri- Anuppur with flyover at Bilaspur	61.6	385.54
Chattisgarh	Bypass at Champa	14	37.64
TOTAL		2,341.4	11,741.32

Source: Ministry of Steel, (2012)

Feeder Routes to Power Plants

As discussed earlier, when power plants are in distant states, feeder routes at the destination end that take coal from trunk routes to the rail sidings at the power plants are not much of a problem because of the low transportation capacity required. However, in-state consumption of coal for power is likely to increase and much of this new capacity will come up in clusters of about 3000-4000 MW each Because such power plants will need to be located not only near coal mines but also near sources of water, it is difficult to predict where these clusters of power plants will come up. In any case, feeder routes from the mines to the power plants will need to be provided. We estimate that such links will be about 70-100 km long and will be required to carry about 20 Mtpa.[6] These links should be designed for heavy haul technology where a rake per day carries 4 Mtpa. It is likely that some of these feeder routes may overlap to some extent, with each other or the feeder routes that bring coal from the mine to the trunk route.

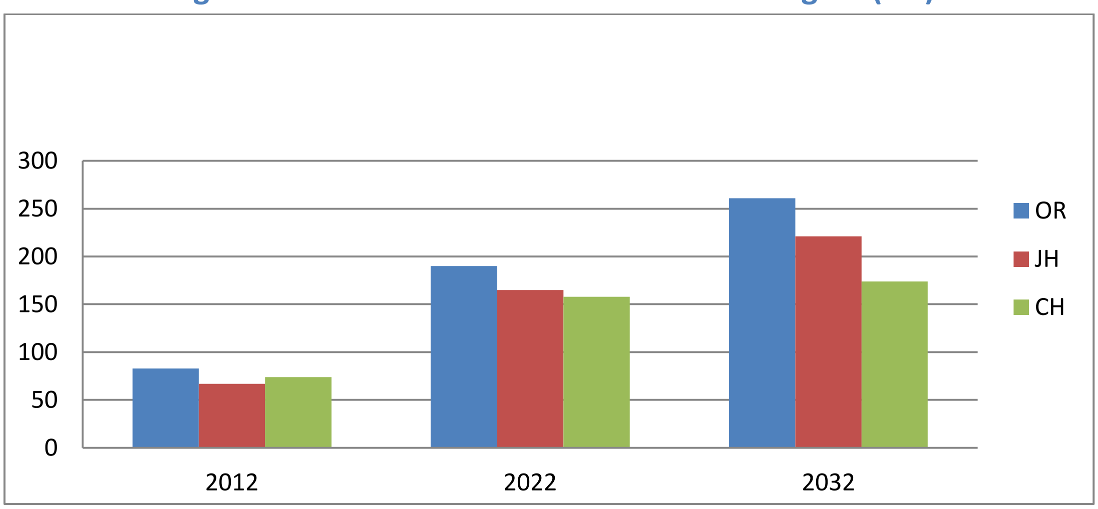
Consumption of domestic coal within coal producing states is expected to grow at about 24 Mt per year in the country. Therefore, roughly one such feeder route to a cluster of power plants will be required every year. Given that most of the increase in production of coal is expected to occur in the tri-state region of Odisha, Jharkhand and Chattisgarh, about one such feeder route will be required in each of the three states every three years.

Need to Focus on Tri-State Region of Odisha, Jharkhand and Chhattisgarh

As Tables 6.4 and 6.5 show, most of the critical feeder routes lie in the three states – Odisha, Jharkhand and Chhattisgarh. This is no coincidence because steel plants and mineral resources particularly coal and iron ore are concentrated in these states. In spite of the importance of these states, the development of the rail network has been inadequate.

As Figures 6.6 and 6.7 show the three states produce more than half of the domestic coal used in the country and are expected to produce about two thirds of it by 2032. In addition, as we have seen in Chapter 3, a quarter of the country's steel production is going to be located in Odisha by 2016-17 and that share is going to remain at that level for the next two decades. Together, the three states will have more than half the steel capacity in the country.

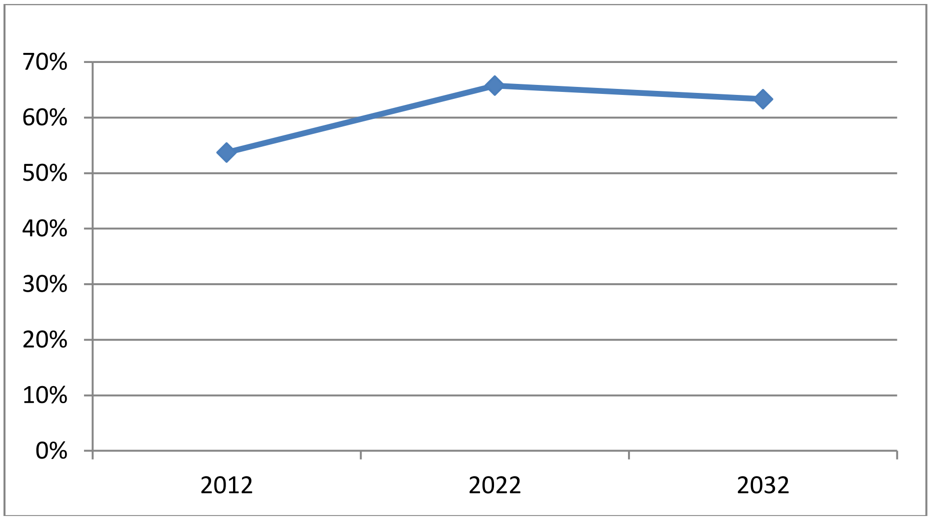
Figure 6.6 Coal Production from Tri-State Region (Mt)



Source: Working Group Research

[6] A 1000 MW power plant requires about 5 Mtpa, so a 4000 MW cluster would requires about 20 Mtpa.

Figure 6.7 Contribution of Tri-State Region to National Coal Production



Sources: Working Group Research

Clearly this tri-state region will be critical for meeting the demand for domestic coal and steel for the next two decades. Ensuring adequate transportation infrastructure in this region is critical for the country's growth. Adequate transport of bulk commodities will also be required for the adjoining states through which the minerals and steel will be carried. Given the importance of the tri-state region and the adjoining areas, one would expect attention has been given to developing the transport infrastructure in the area. Unfortunately, that is not so, and attention needs to be focused on developing infrastructure in the tri-state area.

Private Participation in Rail Connectivity Projects

While the need for rail connectivity for previously unconnected areas is growing, Railways faces resource constraints to fulfill these demands. Therefore, Indian Railways has been working on ways to attract participation of the private sector and to provide an alternative source of funding in rail connectivity projects. The first policy was Railways' Infrastructure for Industry Initiative (R3i) issued in July 2010, but it was not applicable to lines from coal and iron ore mines. In February 2011, Railways introduced a second policy for Rail Connectivity to Coal and Iron Ore Mines (R2CI). More recently, on 10th December 2012, the Cabinet Committee on Infrastructure has approved a new policy on participative models for rail connectivity and capacity augmentation. The new policy supersedes R3i and R2CI.

IR has formulated five participative investment models for its existing shelf of projects and for new projects (MoR, 2012):

1. **Non-Government Railway Model**. This model is designed for developing feeder routes at the source and destination sides. The project developer is responsible for land acquisition, project development and construction with no financial input by IR. The project developer will be paid 95% of the net income from the project.

2. **JV Model** for operationally necessary/bankable sanctioned/to be sanctioned railway projects. This model is for bankable new line or gauge conversion projects that have clearly identifiable stakeholders such as users of the line or ports, mines, exporters, plants or State Governments. The JV will include the Railways and these stakeholders. The JV will get a portion of the freight revenue.
3. **Railway Projects on BOT** awarded through competitive bidding. In some cases it may not be possible to identify stakeholders who will take the lead in making investments. An example is a long rail corridor where revenue is generated from multiple streams. This model is designed for such cases. The concessionaire will be selected through a competitive bidding process, where the funding is provided by the concessionaire where the viability gap funding required would be the bidding parameter. The concessionaire will be paid a user fee based on 50% of the apportioned freight.
4. **Capacity Augmentation with Funding Provided by Customers**. This model is for those cases where some potential beneficiaries of a capacity augmentation project (doubling, multiple lines etc) are willing to fund the project in order to expedite it. The funds with associated interest will be returned to the customers through rebate on freight charges.
5. **Capacity Augmentation with Annuity**. This model is for cases where it is not possible to get funding from a specific user. In this case, the concessionaire would be paid through an annuity.

State Governments can participate in any of the models described above. In particular, if they participate through the first and second models, they can bid out the projects.

IR is to be lauded for attempts to expand private investment in construction of fixed rail infrastructure. The five cases cover most of the circumstances under which private investment could accelerate the development of rail infrastructure. IR will remain a key player even with private participation and will carry out the functions listed below. Therefore, success of the new PPP policy will depend on how well IR is able to execute these functions.

- Certification of the lines will be done by IR in all cases, and in some cases supervision of the construction will also be done by IR.
- Similarly, maintenance of the lines will be done under supervision and certification of IR.
- Operation of the rail network will be carried out by IR and with IR's rolling stock.
- Freight charges will be collected by IR and payments disbursed to the private parites by IR per the terms of the specific agreement.

Large integrated producers of steel or large mining companies are much more likely to enter into these PPP arrangements, but smaller parties may find it difficult to do so. Institutional mechanisms will need to be developed to facilitate coordination among SMEs and large firms in the same area to pool their resources to create common infrastructure (MoS, 2012).

First Mile Connectivity

Coal and iron ore are generally transported from coal mines to the nearest rail siding by road. In many cases the evacuation of material is hampered by the following factors: (1) a lack of adequate and appropriate material handling infrastructure at the mine and at the rail siding; (2)

inadequate road capacity from the mine head to the railway siding; (3) an occasional shortage of railway rakes. Efforts are being made to augment material loading and unloading facilities and increase road transportation capacity. The shortage of rail rolling stock is often a seasonal issue which is exacerbated by congestion on the lines. It is expected that as capacity constraints are removed the shortage of rolling stock will also be addressed. However, as we discuss later, as the volume of coal that needs to be transported increases dramatically, additional rolling stock will be required.

Creation of road infrastructure takes time. Therefore, advance planning is essential to develop the required roads for movement of coal from mine-heads to rail-heads. However, such planning is rarely done. It has also been suggested that the existing fair-weather roads in high growth coal fields, particularly where captive coal blocks are expected to become operative, be converted into all-weather express coal corridors (MoC, 2011).

Due to the poor quality of road transportation, the loading at rail sidings shows an annual pattern: it peaks during the winter months and declines during the summer and monsoon season. The mine company is unable to utilize the rail capacity optimally, and the unused capacity is lost. Railways estimates that the drop in loading results in a loss of about 50 rakes per day for a substantial part of the year (Roy, 2012).

Further, because the coal from the mines in the traditional coal fields has to be moved through heavily populated villages, and is vulnerable to blockage and other disturbances due to socio-political events, the following suggestions have been made about transportation from mine-heads to rail-heads (MoC, 2011).

1. Wherever possible, long-distance conveyor belt systems should be used for movement. This will reduce the environmental impact of road transport.
2. Siding rationalization plans should be developed.
3. Coal mining companies should consider developing a hub-based system for transporting coal from existing mines wherever feasible.

Merry-Go-Round (MGR) Systems

Most pithead plants, particularly the large ones get their coal using merry-go-round (MGR) systems. As discussed earlier in this chapter, almost 20 percent of the country's domestic coal is transported by MGR. Furthermore, as a greater percentage of coal will be used within the producing state, the share of movement by MGR will grow. Therefore, it is important that this mode of transport is also efficient.

Sometimes there is a delay in the development of the mining and MGR system, and the power plant is completed before the mine or the MGR system is functional. In such cases, as a stop gap measure, coal is brought from another location in case of delay in the mine, or Indian Railways is asked to transport coal from the mine in case of delay in the MGR system. Such stop-gap arrangements become difficult to get out of due to socio-political reasons. Therefore, synchronization needs to be ensured between the development of the pithead power plant and the mine and transport system (MoC, 2011).

In addition, Indian Railways states that often pithead plants with MGR require augmentation of their coal supplies by Indian Railways. But often the MGR systems are not designed for handling rakes from outside (Roy, 2012). This results in delays. When pithead plants are proposed in the future, it would be advisable that the MGR systems be designed to handle rakes from the Indian Railways. Further, it has been suggested by Indian Railways that because of their expertise on rail systems, they will be able to operate the MGR systems at lower cost (Roy, 2012). Therefore, they suggest, involving Indian Railways as a partner in the running of MGR systems.

Last-Mile Connectivity

Transport of unsized coal sometimes results in delays in unloading, specially of bottom discharge wagons because large pieces get stuck. Sizing of coal before dispatch would avoid this problem and ensure faster unloading of rakes. In addition it would increase the carrying capacity of wagons through better compaction.

Furthermore, sometimes there are delays in unloading because the material handling system at the receiving power plant cannot handle all types of wagons. Either a power plant should be designed to handle a particular type of wagon and only that type of wagon should be sent to that power plant, or all power plants should be capable of handling all types of wagons – bottom discharge, tippler, etc. While the first option may be more economic from the perspective of the power plant, it may not be feasible given the limited rolling stock available with the Railways. In either case, the turn-around time of rakes at power plants would be greatly improved.

There is also need to improve the bunker capacities, conveyor belt capacities and stacking capacities at power plants. As the tonnage per train that is discharged at the power plant increases, bunkers will need to be emptied and their content stored at the power plant site, otherwise overfull bunkers will become a bottleneck slowing down the unloading of trains. Thus additional stacking capacity will be required.

Build-Up of Coal Stocks at Pit-Heads

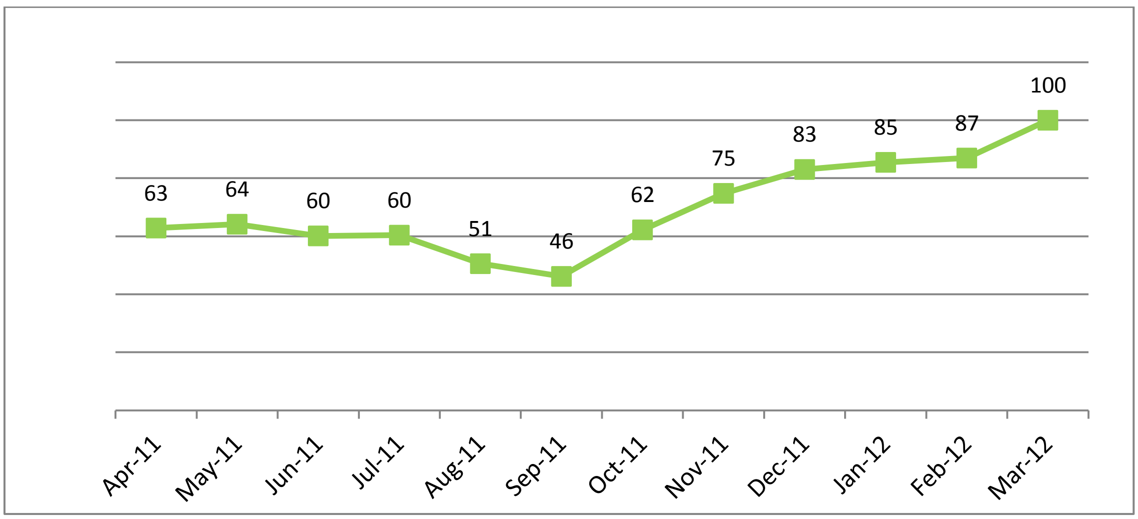
There has been a spate of media reports about the build-up of coal stocks at the pit-heads of mines and the irony of this large amount of coal awaiting transportation while there is a shortage of coal at many power plants (Business Today, 2012). At the end of 2011-12 the pit-head stocks were recorded at 74 Mt.

Monthly Variation in Coal Production and Pit-Head Stocks

Coal production and road transportation to rail sidings follow a pattern over the year where they peak during the winter months and decline during the summer and monsoon season (Figure 6.8). Railways is unable to meet this wide variation in demand and consequently pit-head stocks peak in the winter months and decline in the summer and monsoon months (Figure 6.9).

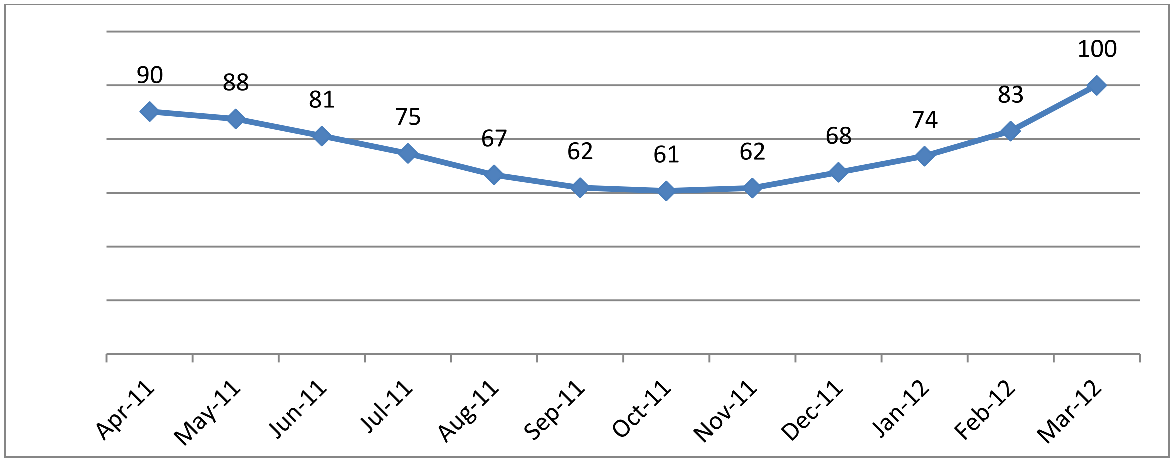
Annual pit-head stocks are reported at the end of March when they are at the highest level. For year by year comparison, the minimum pit-head stock may be a more appropriate number because it gives the amount of coal that remains at the pit-head and is not picked up by Railways. That number is lower; about 60 percent of the peak stock of coal during the year.

Figure 6.8 Monthly Production of Raw Coal as a Percent of Max Monthly Production (2011-12)



Source: Coal Controller's Organization (2012).

Figure 6.9 Month-Wise Pit-Head Closing Stock of Coal in 2011-12 (percent) Raw Coal



Source: Coal Controller's Organization (2012).

Cumulative Effect of Mismatch between Production and Off-Take

Pit-head stocks are the cumulative effect of a mismatch between production and the amount transported by Railways. In order to assess the extent of the mismatch, Table 6.6 shows the annual increase in the pit-head stock for the last ten years. As discussed above, we have used the minimum monthly stock as representative of the stock in a particular year.

Table 6.6 Annual Increase in Pit-Head Stock (Mt)

Year	Min Monthly Pit-Head Closing Stock	Increase in Stock in Year
2002-03	9.8	--
2003-04	10.1	0.3
2004-05	10.5	0.4
2005-06	15.9	5.5
2006-07	24.3	8.3
2007-08	66.4	42.1
2008-09	28.0	-38.4
2009-10	38.4	10.4
2010-11	49.0	10.6
2011-12	45.0	-4.0

Source: Coal Controller's Organization (2012)

Some observations from the table:

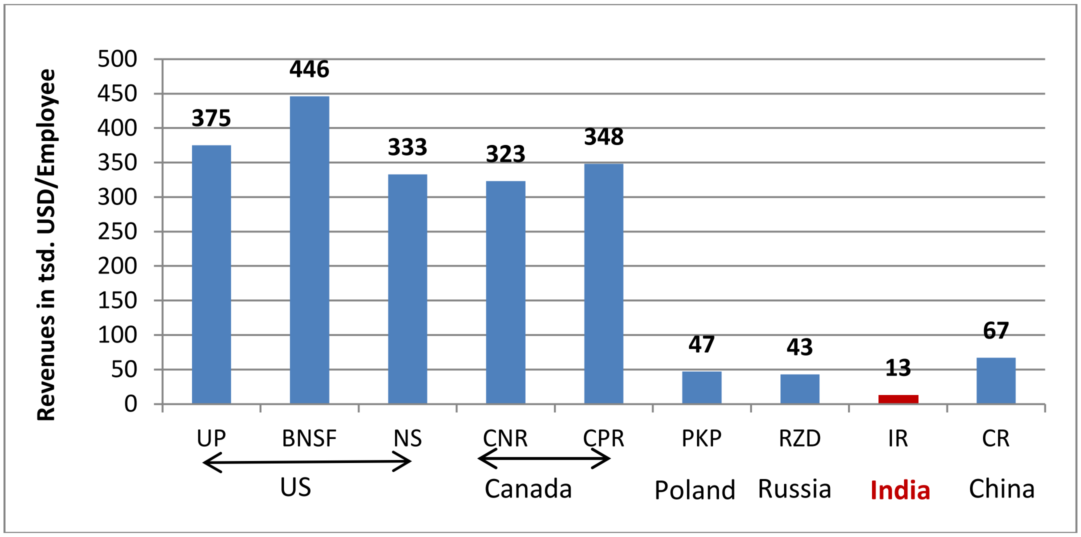
1. Stocks started to increase around 2006-07 and have generally remained high since then.
2. In 2007-08 the pit-head stocks increased dramatically by 42 Mt, but in 2008-09 there was an almost equal reduction in the stock. This is difficult to explain because the production in these years was not abnormally high or low; it was 457 Mt in 2007-08 and 493 Mt in 2008-09.
3. Excepting the two anomalous years, we see that the annual mismatch in production and transport by Railways has varied between 10.6 Mt (2010-11) and -4 Mt (2011-12).
4. The cumulative effect of a mismatch between production of coal and the amount lifted by Railways has led to about 45 Mt of coal that is lying at pit-heads. This is a significant amount, however, it is about 60 percent of the number (74 Mt) that is often cited.

The annual build-up of stocks at pit-heads indicates that there is no spare capacity in the rail transport system. It is an early warning that the rail network or the amount of rolling stock or both are operating at their full capacity. If the amount of coal produced at the mines increases, as would be desirable, then it is very likely that there will not be sufficient capacity in the transport system to move that coal to power and steel plants. Currently we are at a low-level equilibrium where production of coal is not increasing or is increasing very slowly and the transport system is almost able to keep up. However, if coal production increases dramatically, the transportation system will become a bottleneck blocking the value of increased production from benefiting the economy.

Rail Efficiency and Technology Improvements

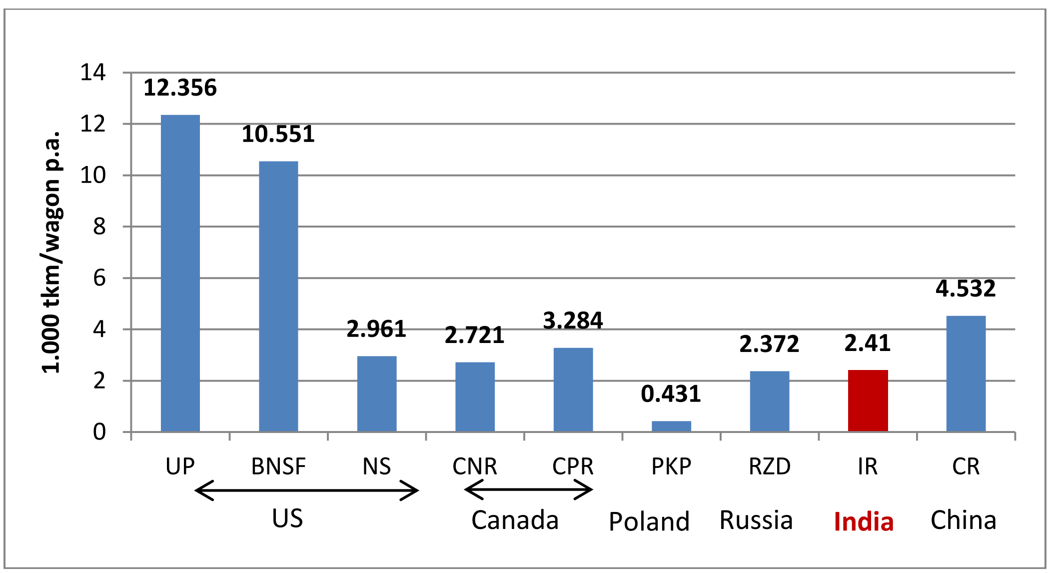
Freight transportation in India is far less efficient than rail in other countries. Figures 6.10 and 6.11 compare two indicators of efficiency of India with a peer group of countries. India's staff efficiency measured in revenues per employee is the lowest in the group. It is only $13,000 per employee compared with the best of $446,000 per employee. In wagon efficiency, India's wagons over a year provide transportation of 2.4 Mt-km which is much lower than the best of about 12.4 Mt-km.

Figure 6.10 Comparison of Staff Efficiency of Railways in Select Countries



Source: Jahncke, (2012).

Figure 6.11 Comparison of Wagon Efficiency in Select Countries

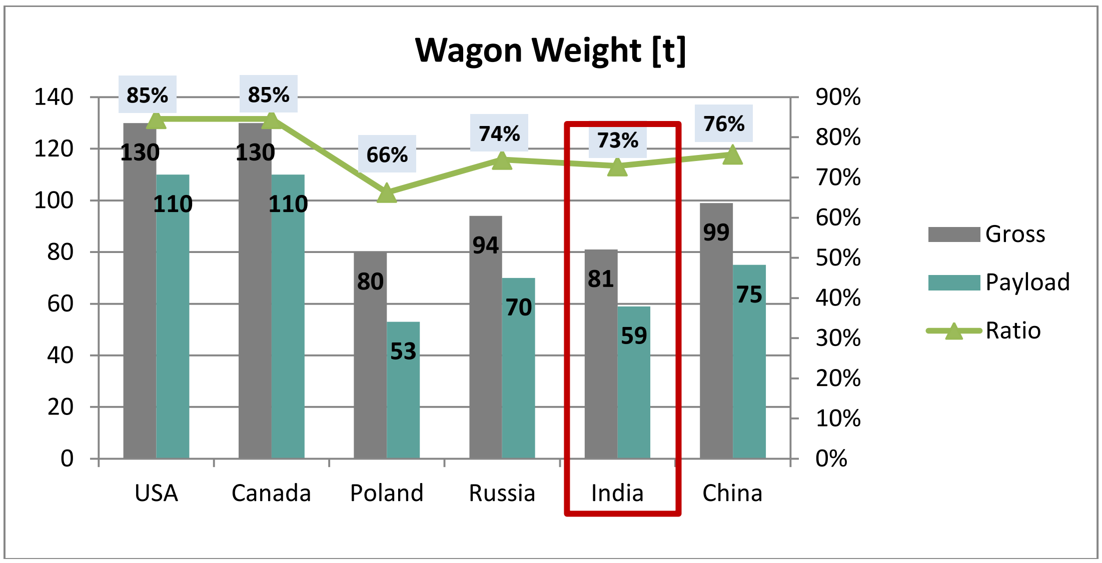


Source: Jahncke, (2012).

Transportation cost is a large fraction of the price that the customer pays. For states that are far from coal mines, rail transportation can often be more than the price of coal at the mine-mouth, effectively more than doubling the cost of fuel for power plants. Therefore, it is important that the transport cost be kept low. Furthermore, railways main competitive advantage is its lower cost and its important that it keep costs low, otherwise, its market share will erode even faster than it already is eroding.

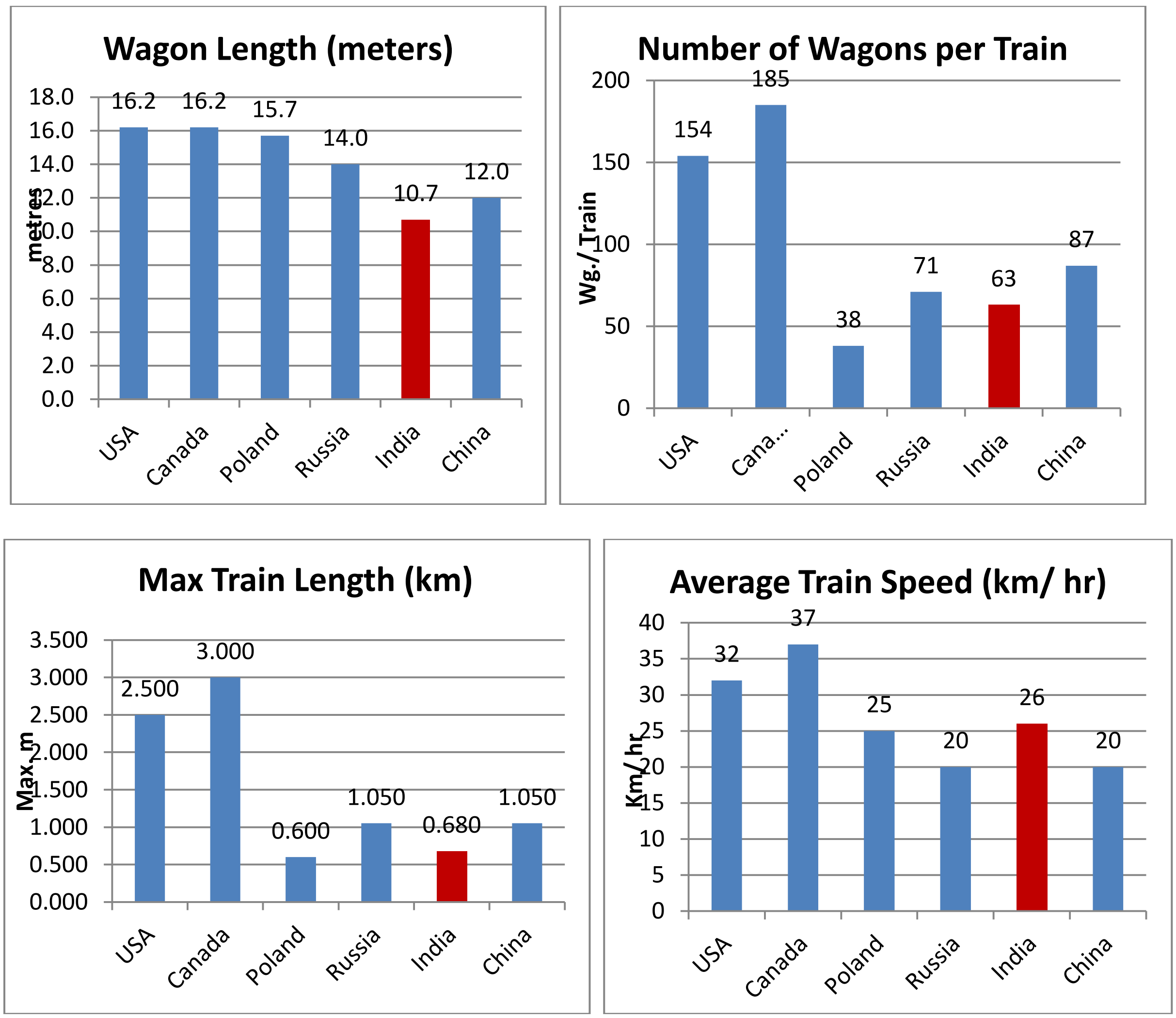
Transportation costs per tonne can be lowered by using well-loaded trains with a high net weight to gross weight ratio. How does India compare on these measures? Indian trains are comparable on most loading parameters with trains in Poland, Russia and China. However, when compared with trains in USA and Canada, the loading levels are considerably lower. For example, Figure 6.12 shows that Indian wagons have a net to gross ratio of 73 percent which is significantly lower than the world's best of about 85 percent, which means that Indian wagons are spending a larger fraction of fuel to carry the weight of the wagon itself. Further, the Indian trains which have a maximum length of 680 meters are much shorter than trains in US and Canada which can be as long as 2.5 to 3 km (see Figure 6.13). The problem is compounded by the lower average speed of Indian trains (26 kmph) compared to the speeds in US and Canada (32-37 kmph) (Jahncke, 2012).

Figure 6.12 Comparison of Wagon Weight and Payload to Gross Weight for Select Countries



Source: Jahncke, (2012)

Figure 6.13 Country-Wise Comparison of Components of Loading Level of Trains



Source: Jahncke, (2012)

Indian Railways is planning to address these issues. The report of the Working Group on Railways for the 12th Plan discusses a strategy of "heavier, longer, faster" which includes the following measures (MoR, 2012):

- Use of 25 tonne axle load wagons for iron ore, and planning for 30 tonne axle load
- Moving overall regime from 22.8 tonnes to 23.5 tonnes axle load.
- Greater use of long haul trains. As an interim measure, on some sections, Indian Railways is running two trains in tandem, effectively as one train to reduce the impact of capacity constraints (Roy, 2012).
- New rolling stock and infrastructure is being designed so that trains will run at 100 kmph empty and 75 kmph when loaded. Efforts are ongoing so that even fully loaded trains would run at 100 kmph.

However, in order to carry the much higher volumes of bulk commodities that will need to be transported over the next two decades, Indian Railways will have to make big strides in improvements of transport infrastructure. The focus should be on:

- Infrastructure enabling higher axle loads;
- Specialized wagon and loading technology;
- Longer trains.

Investment Required

Prioritization of Investments in Rail Network

Given the limited resources available for further development of the railway network, priority should be based on two principles: (1) those route developments that have the highest impact should be given priority over others; and (2) urgently required route developments should be given priority over those where the requirement is expected some time later.

Based on these two principles, we suggest the following priorities:

1. **Critical Feeder Routes for Coal and Iron & Steel**. All the additional coal or iron ore that is to be transported by rail will make use of these feeder routes. A delay in providing these routes will affect availability of coal and iron ore for the entire country.
2. **Construction of DFCs Starting from Eastern End.** As discussed earlier in this chapter, construction of DFCs must start at the end located in the coal bearing region, for two reasons: (1) coal bearing traffic will be the highest nearest to the coal region; and (2) transport of coal within coal bearing states or to neighboring states are likely to use short sections of the DFCs.
3. **Highest Priority to the Eastern DFC.** The Eastern DFC must get very high priority because it is likely to carry 50-70 percent of the coal traffic to distant states from the coal-source states. Therefore we suggest that the Eastern DFC be built within the 12th Plan. The Western DFC is required for container traffic (not discussed here) and is already slated for completion by the end of the 12th Plan, however, because it is not as important for movement of bulk materials, we suggest that about 80 percent of the investment be done in the 12th Plan and the remaining 20 percent in the 13th Plan. For the E-W, East Coast and N-S DFCs, which are scheduled to be operational by the end of the 13th Plan, to keep the investment in the 12th Plan from becoming burdensome, we suggest that only a third of the investment be made in the 12th Plan and the remaining investment and construction take place in the 13th Plan. Because the Southern DFC is not important for movement of bulk commodity, we suggest that it be shifted to the 14th and 15th Plans.
4. **Additional Augmentation.** In addition to DFCs, there are other routes that will require augmentation. We have removed the critical feeder routes from this list of additional augmentation that will be required, because the critical feeder routes will be covered in the 12th Plan. For the remaining augmentation, we suggest that it be spread out evenly over the 13th-15th Plans, with augmentation to routes closest to the coal and iron-ore regions getting priority.

Investment in Railways for Bulk Transport

Investment in railways is broken into two parts: (1) investment in rolling stock; and (2) investment in the rail network. First we estimate the required investment in rolling stock and terminals. As the amount of bulk material that needs to be transported increases, the number of wagons, locomotives and terminals will have to increase. We estimate that an additional Mtpa to be carried requires an investment of about Rs 150 crore in rolling stock and terminals. Details of the estimate based on the requirements and costs for wagons, locomotives and terminals are given in Annex III. 6.2. Using estimates of the amount of bulk material that will be required from chapters 4 and 5, we estimate the increase in the amount of bulk material that will have to be transported in the terminal years of the next four five-year plans as shown in Table 6.7.

Table 6.7 Required Investment in Rolling Stock and Terminals to Carry Additional Bulk Materials

Category of Investment	12th Plan	13th Plan	14th Plan	15th Plan
Increase in thermal coal transported by end of each FYP (Mt)	187	264	251	250
Increase in iron ore transported by end of each FYP (Mt)	77	129	180	210
Increase in coking coal transported by end of each FYP (Mt)	30	49	68	77
Total increase in bulk material transported by end of each FYP (Mt)	294	442	499	537
Required investment in rolling stock and terminals (Rs crore)	44,138	66,300	74,850	80,550

Note: It is assumed that each additional Mtpa that has to be carried will require investment of Rs 150 crore (For details see Annex III. 6.2)

Next we look at the total investment required for railways for transporting bulk materials. Based on the principles for prioritizing investments described in the previous section, we suggest the plan-wise investment for the Railways given in Table 6.8 below.

Table 6.8 Suggested Plan-Wise Investment for Railways (Rs Crore)

Category of Investment	12th Plan	13th Plan	14th Plan	15th Plan
Critical Feeder Routes - Coal	3,150			
Critical Feeder Routes - Iron and Steel	11,740			
Feeder Routes for Power Plant Clusters	1,500	1,500	1,500	1,500
Eastern DFC	45,975			
Western DFC	26,845	11,505		
E-W DFC	16,467	32,933		
East Coast DFC	9,142	18,283		
N-S DFC	18,250	36,500		
Southern DFC			11,275	11,275
Any additional augmentation		48,185	48,185	48,185
Rolling Stock and Terminals	44,138	66,300	74,850	80,550
TOTAL	177,207	215,206	135,810	141,510

Source: Working Group Research

Summary

While examining the pattern of movement of coal that is expected over the next two decades, we find that as the economy grows, domestic coal will be used closer to home. Consumption of coal within coal producing states is expected to increase from 44 percent currently to 60 percent by 2031-32. If we include transport of coal to neighboring states, we find that about 70 percent of domestic coal in 2031-32 will be used within coal producing regions. As a result, a very large portion of domestic coal will not make extensive use of DFCs, even though some transport within coal producing regions may occur over short sections of DFCs. Similarly, most of the imported coal (73-82 percent) will be used by coastal states. Under these circumstances where a progressively greater share of coal will used within the source and coastal states, it is expected that the share of short rail routes, road, MGR and conveyor belts or ropes will grow. Therefore, attention must be focused on these modes of transporting domestic coal.

Even the traffic pattern on the DFCs shows an interesting trend. The Eastern DFC is likely to carry an overwhelming share of the long distance coal traffic, with its share increasing from about half currently to about two-thirds by 2031-32. Excluding the Southern DFC which is not expected to carry much coal, the other DFCs have a much smaller and about equal share of the long distance coal traffic.

Feeder routes at the source-end are critically important for the effectiveness of the bulk transport system. All the coal and iron-ore traffic that moves by rail must be transported on these routes. There are some critical feeder routes for coal and iron-ore that need to be completed. For some of them, work was started a long time ago while for others even cost estimates have not been developed. Together these routes will cost about Rs 3,500 crore for coal and Rs. 11,740 crore for steel; relatively small amounts. These critical routes must be completed on the highest priority.

Freight transport in India is far less efficient than rail in other countries. There is a great need for upgrading and modernizing equipment, rolling stock and rail lines. As the Railways recognizes, trains must be heavier, longer and faster in order to maximize the use of existing infrastructure.

Investments in the rail network need to be prioritized on two characteristics: (1) level of impact of the investment; and (2) urgencyof the route development. Based on these two principles, the following priority list has been developed:

1. Critical feeder routes for coal and iron-ore
2. Construction of DFCs starting from the coal bearing area
3. Priority to the Eastern DFC and it should be done in the 12th Plan period. Investment in other DFCs can be spread over the four plan periods.

Based on this priority list, plan-wise investments have been suggested, with total investments about Rs. 670,000 crore over the twenty year period encompassing the 12th, 13th, 14th and 15th Plans. The investment is relatively higher in the 12th and 13th Plan, with the 13th Plan getting the maximum investment. We expect that by the 14th and 15th Plan, the major investments will have been made and thus the requirements in the 14th and 15th Plan will be lower.

Chapter 7. Infrastructure Requirements and Investment Planning for Ports

As described in Chapters 4 and 5, the level of imports of thermal and coking coal and POL will grow dramatically in the next two decades. Will our ports be able to handle the traffic given that many are already stretched to the limits of their capacity? Efforts are being made to improve the performance of India's ports. However, in addition to port-wise development plans, a comprehensive strategy needs to be evolved for the port sector. As a way to kick-start the discussion, we outline some issues that need to be considered in the development of a strategy for the port sector.

There are also issues of how poorly our ports compare with international benchmarks of performance. Perhaps most important, the level of connectivity of the ports to the hinterland needs to be considered because even the most modern and best performing port would be useless if it lacked sufficient connectivity to the destination of materials to be imported.

Table 7.1 Projected Port Traffic for Coal and POL (Mt)

Commodity	2011-12	2016-17	2021-22	2026-27	2031-32
Thermal Coal	73	88	138	266	355
Coking Coal	32	65	108	173	238
POL	329	475	572	702	864
TOTAL	434	628	818	1,141	1,457

Source: Table 4.5, Table 5.13 and Table 5.5.

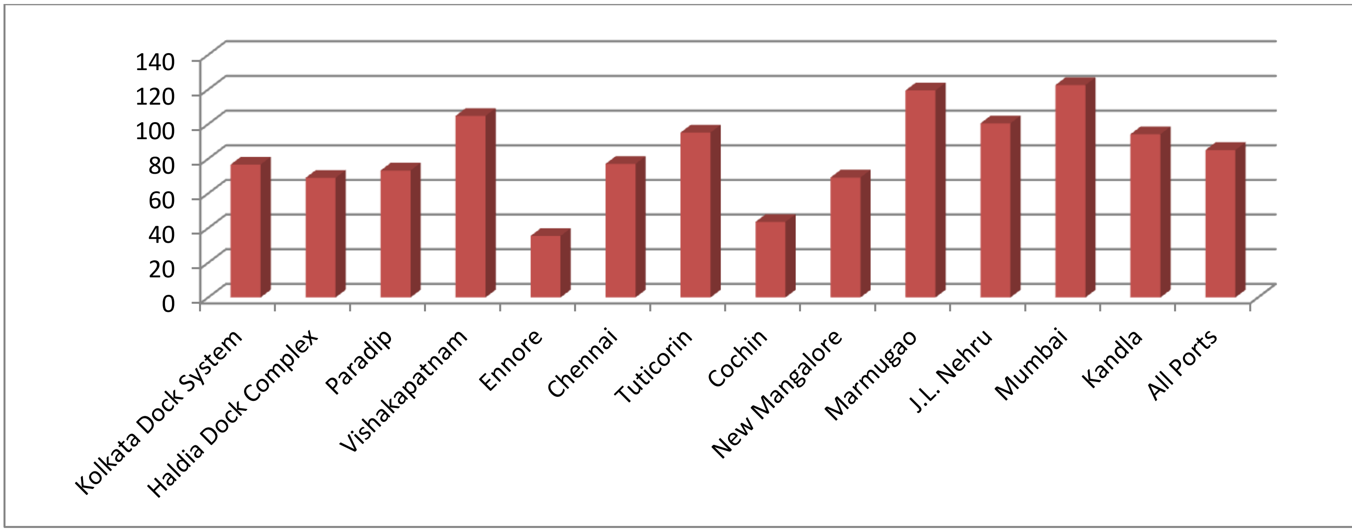
Before the ban by the Supreme Court, exports of iron ore were increasing dramatically. Over the nine year period from 2000-01 to 2009-10, they increased by more than three times (MoS, 12th Plan Rpt). In 2009-10, about 53 percent of the iron ore produced was exported. Because of the Supreme Court ban, there was a decline in 2010-11. According to the Ministry of Steel, because the iron ore resources are ultimately limited, the resources should be conserved for the domestic steel industry. Therefore, development of additional mining capacity should be undertaken in a "well-calibrated" way so that excess capacity does not result in an incentive to export, while ensuring that iron-ore will be available for domestic steel industry as it expands. Keeping this mind, in this report we have not focused on transportation requirements for the export of iron ore.

In this chapter, we first discuss the performance of ports. After that we discuss the importance of coastal shipping and how its share can be increased. Then we focus on issues related to further development of ports. As part of that discussion, we review the traffic for coal and POL that is expected in the various coastal states. We follow that with a brief discussion of the investment that is likely to be required for ports.

Port Capacity

India's ports are stretched to their capacity. As Figure 7.1 shows the capacity utilization of the major ports averages around 85 percent with at least four operating at an utilization of 100 percent or more. International norms recommend that capacity utilization be below 70 percent to avoid delays.

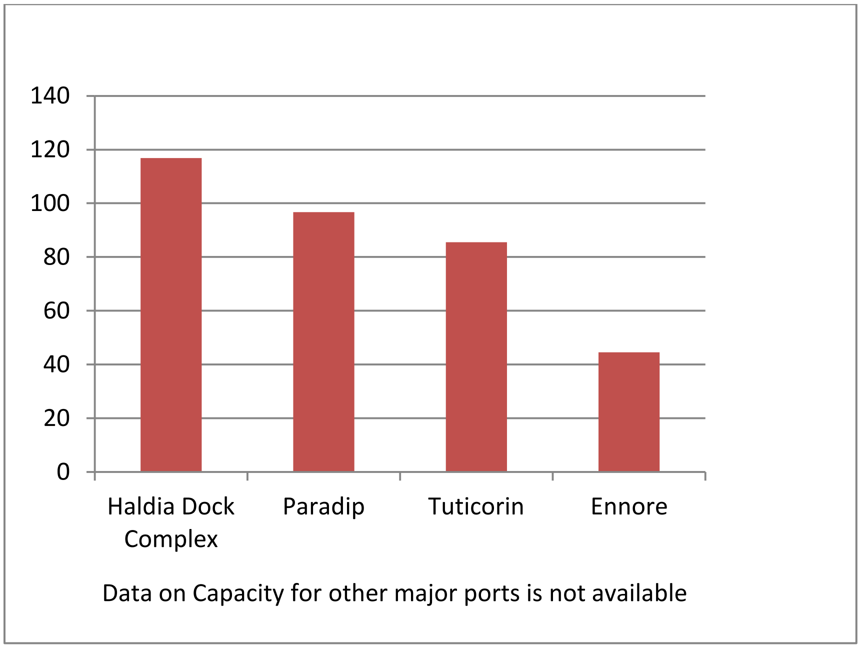
Figure 7.1 Percent Capacity Utilization of Major Ports



Source: Ministry of Shipping, (2012).

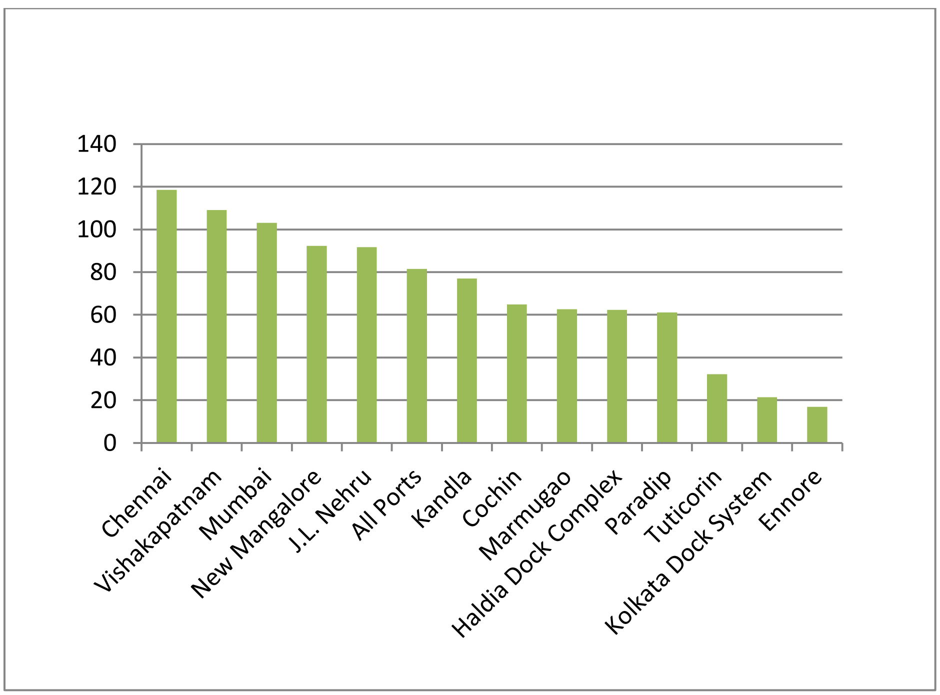
Commodity-wise capacity utilization for coal and POL which is of greater interest here is shown in Figures 7.2and 7.3. Unfortunately, capacity utilization for coal is only available for four major ports, but for POL we have more complete data. These commodity-wise capacity utilization figures reaffirm the same picture of ports stretched to capacity. For coal, three out of four ports have capacity utilization above 80 percent while the international norm is 70 percent. For POL, about half the major ports have capacity utilization above 70 percent.

Figure 7.2 Percent Capacity Utilization for Coal at Major Ports



Source: Ministry of Shipping, 2012.

Figure 7.3 Capacity Utilization for POL at Major Ports



Source: Ministry of Shipping, 2012.

Port Performance

The lack of capacity at the ports and consequent congestion and delays are reflected in the poor performance of the major ports. Table 7.2 provides some measures of performance of Indian ports.

Table 7.2 Performance of Major Ports

Performance Metric	Average for Major Ports
Pre-berthing dwell time	2.1 days
Turn-around time	4.5 days
Output per ship-berth-day	11,112 tonnes

Source: Indian Ports Association (2012)

In spite of a lot of effort, we have not been able to get international benchmarks for these performance metrics that would provide a fair "apples to apples" comparison with Indian ports. However, one indicator of the penalty that is imposed on ships at Indian ports due to lack of adequate capacity is that

> There is no concept of "pre-berthing detention" as such in world class ports, the capacity is much more than the actual traffic and the planning is also done on those lines. Hence there is no question of any ship waiting at anchorage. (MoShipping, 2011)

In contrast on average ships have to wait for more than 2 days to get a berth at an Indian port.

While data on port performance is not available for bulk commodities, the Maritime Agenda does have a comparison of major Indian ports with Singapore for handling of container ships. The turn-around time for container vessels at major Indian ports is 1.77 days compared to just 0.50 days at Singapore port. The cargo dwell time for containers at major Indian ports is 3.78 days while it is just 0.60 days for Singapore. Even though the performance of a port on handling of bulk cargo can be different from containers, these numbers do give an idea of the gap between the performance of Indian ports and world-class ports.

Pre-berthing detention is directly related to congestion at the port and hence the lack of capacity. Average turn-around time is the time required to load, discharge and service a vessel. Major factors that drive vessel turn-around time is the amount of traffic to be loaded or unloaded (again related to capacity), distance from anchor point to the berth, efficiency of the port authority in piloting or tugging the vessel, and most significantly the efficiency of the terminal operator in handling the vessel. Average output per ship-berth day is related to the last factor affecting vessel turn around time – the efficiency of the terminal operator in handling the vessel. Of course, there are other factors that affect output such as the composition of the traffic at the port.

Some of the reason for poor performance at the ports are listed below (PwC, 2009):

- **Low Level of Mechanization**. Indian ports lack modern technology to handle coal and other bulk cargo. There are a limited number of berths available for handling bulk cargo with mechanized ore handling capability. (Paradip Port is the only one with a dedicated berth for coal handling.) The low level of mechanization, in combination with other factors leads to low productivity.

- **Inadequate Cargo Handling Equipment**. Even the equipment that exists in the ports is old and breaks down frequently and takes long to be repaired resulting in long down-times, exacerbating the problem of low productivity.

- **Inadequate Navigational Aids and Facilities**. Most of the ports are not equipped with a vessel traffic management system (VTMS). Furthermore, the number of tug-boats and launches are likely to be insufficient for the increased traffic that is expected.

- **Insufficient Use of Information Technology**. Resources and equipment at the ports are spread-out and without good ERP systems, are under-utilized.

- **Insufficient Drafts**. The drafts at Indian ports have been very low and not in keeping with the increase in ship sizes that is occurring around the world. The older ports have drafts as low as 7 meters while a few of the new ports go up to 16 meters. For shipping of bulk materials such as coal and iron ore, the larger the ship the better because of the economies of scale (ECORYS, 2012). As Table 7.3 below shows, **transport costs for bulk shipping can come down by more than 40 percent by increasing the size of the ship that a port can handle from Handy Size to Cape Size**. However, as the size of the ship increases the required draft also increases from 10 meters for a Handy Size vessel to 18 meters for a Cape Size vessel.

Table 7.3 Effect of Vessel Size on Transport Costs

Ship Size	Dead Weight (tonnes)	Draft Reqd (meters)	Transport Costs (indexed to Handy Size as 100)
Handy Size	35,000	10	100
Panamax	80,000	12	76
Cape Size	180,000	18	58

Source: ECORYS (2012).

- **Insufficient Storage Space**. Lack of adequate stacking space results in less clear space at the port which in turn, leads to higher vessel turn round time.

Coastal Shipping[7]

Coastal shipping is an important mode of transport for bulk commodities that has several advantages and can reduce the burden on other modes. Coastal shipping uses less fuel (~5 g/tonne-km) compared to road (~ 31 g/tonne-km) and rail (~ 9 g/tonne-km). Consequently, it is less expensive and has a lower environmental impact than road and rail transport. Currently, coastal shipping carries about only about 7 percent of the freight traffic, well below its potential given India's long coastline. In comparison, the share of coastal shipping is 15 percent in the US and 43 percent in the EU. Even at the current low level of penetration of coastal shipping, about two-thirds of the total traffic carried by coastal shipping is for POL, coal and iron-ore. Therefore, coastal shipping can play a significant role in the bulk transport of these commodities.

Comparison of Transportation Costs Using Coastal Shipping

In order to illustrate the very high cost advantage of coastal shipping and to understand some of the reasons why coastal shipping is even then not preferred, Table 7.4 compares the costs for transporting coal from Mahanadi Coalfields Ltd (MCL) in Odisha to the coastal states namely, AP, Tamil Nadu, Karnataka, Maharashtra and Gujarat by coastal shipping with the costs of rail transport. For coastal shipping it is assumed that coal is transported from the mine by rail to Paradip from where it is shipped to the destination ports in the states. One destination port has been selected for each of the states. For estimating the costs of rail transport it is assumed that coal is transported by rail from the mine to the geographical center of the state. For both rail and coastal shipping, costs are based on tariffs the customer would have to pay. Ideally, costs should be compared but it was not possible to get actual costs for transportation and handling, and so we have used tariffs as proxies for the costs.

As Table 7.4 shows, in spite of the much longer distance ships would have to travel, the freight charge in all cases are lower for coastal shipping even for Kandla port where the distance travelled by coastal ship is much greater than the distance travelled by rail which cuts across the country. For Vizag, Ennore and New Mangalore, shipping freight charges are 25 percent-50 percent of the rail freight charges. However, it should also be noted that when comparing total costs that the customer would have to pay, it is cost effective to use coastal shipping only for transporting coal to Ennore. For all other destination ports in the table, the customer would have to pay more in total for coastal shipping, because of the other charges. Handling charges to be paid at Paradip to load the ship and at the destination port to unload the ship, and freight charges would have to be paid to bring the coal from the mine to the port of origin (Paradip in this example) and to take the coal from the port to the power plant. Together the additional charges are almost as much or even more than the shipping freight charges. Thus we see that the cost advantage of coastal shipping is not realized because of high handling charges and first and last mile connectivity.

[7] This section, except the table and analysis of costs is based on information in the report by Ernst & Young (2011).

Table 7.4 Comparison of Rail and Coastal Shipping Costs (in Rs/tonne)

(Coal from Mahanadi Coalfields, Odisha to destination port via Paradip for coastal shipping)						
Destination Port	Rail	Coastal Shipping				
	Freight	Freight	Handling	Rail - Mine to Origin Port	Rail - Dest Port to Power Plant	Total
Vizag	867	173	368	327	91	959
Ennore	1,164	243	368	327	91	1,029
New Mangalore	1,248	646	368	327	91	1,432
Mumbai	994	820	368	327	91	1,606
Kandla	1,445	1,173	368	327	91	1,959

Note: Freight charges for coastal shipping (Rs 0.23/tonne-km), and handling charges are based on TANGEDCO costs for transporting coal from Paradip to Ennore.

Source: Working Group Research and TANGEDCO (2012).

Reasons for Slow Adoption of Coastal Shipping

There are several factors which contribute to the high handling charge for coastal shipping and the lack of interest in coastal shipping:

- Major ports do not have separate berthing and material handling facilties for coastal vessels which are smaller, and this results in higher costs and longer turn-around times.
- Minor ports do not have adequate material handling facilities and often the equipment is not working.
- Lack of consolidation and resulting large number of small players hampers economies of scale.
- The other modes of transport such as roads, railways and aviation enjoy subsidies and credit facilities that are not available to coastal shipping. Effectively, this increases the relative cost of coastal shipping.
- Connectivity between ports and the hinterland is inadequate.
- Qualified personnel are not available because most prefer to move to overseas ships that have better perquisites and tax benefits.
- Lack of an integrated transport policy which encourages and promotes inter-sectoral coordination

Recommendations for Promoting Coastal Shipping

Over the years, the government has taken several initiatives to remove some of the disadvantages suffered by the coastal shipping industry. In 2004, a special cell was established for development of coastal shipping. As a result, in 2008, the manning scales for coastal ships were relaxed so that they were more consistent with the smaller size of the vessels, and did not impose an onerous staff requirement. In recognition of the fact that the vessels engaged in coastal shipping were smaller and did not require the same construction, equipment and safety requirements as ocean-going vessels, there was an exemption for coastal ships from these requirements of the Merchant Shipping Act, and now coastal ships are subject to requirements that are more appropriate for the kind of service for which the ships are deployed. In addition, policies have been proposed to have dedicated facilities for coastal shipping and to develop minor ports to encourage coastal shipping.

In spite of these initiatives, growth in coastal shipping has been sluggish relative to its potential. While appropriate policies have been formulated, there has been a lack of framework for implementation. An implementation framework is required that would: (1) include inputs from all stakeholders on barriers to effective implementation and suggestions for overcoming them; and (2) assign responsibility and time-lines for various tasks.

Strategic Considerations for Further Development of Ports

As we have seen, currently Indian ports have severe limitations of capacity to handle the bulk cargo traffic. Clearly considerable efforts and investment will be required to upgrade the ports to not only service the fourfold increase in traffic but also meet the performance benchmarks based on international standards. Efforts are being made to improve the performance of individual ports. However, a broader and coherent strategy needs to be developed for the overall ports sector based on a vision for the sector.

Some of the issues that need to be addressed as the country develops its port strategy:

- Mega ports provide very significant economies of scale and most of the world's major economies have a few mega ports. How many mega ports should there be in the country and where should they be located?
- Should ports for bulk commodities be separate from those for other cargo?
- Should ports for coastal shipping be separate from ports for international traffic?

Consideration of these issues, particularly regarding the number and location of mega ports requires a much more intensive study using detailed modeling which is beyond the scope of this study. In this report, we look at some of the issues that will need to be considered in addressing these issues and give some suggestions on what needs to be done.

Number and Location of Mega Ports

The performance of Indian ports must improve, otherwise because of the inefficiencies, India's imports will become more expensive and the country will have less exports. However, improvement of performance requires capital investment to create infrastructure for handling bigger ships and faster handling of cargo. The number and location of mega ports will need to be based on a balancing of these costs and the returns on investment based on estimates of port traffic.

In order to facilitate the discussion on the number and location of mega ports, we first attempt to get a better understanding of the pattern of port traffic that is likely to emerge over the next two decades in the coastal states, as described in the next sub-section.

Expected Port Traffic for Bulk Commodities

For coal, current levels of imported coal use for each state (both coastal and in-land) were obtained from Chapter 4 and 5. We looked at the current level of imports in the coastal states to determine how much of the coal was for consumption within the coastal states and how much was destined for other states. For each land-locked state, we were also able to make an educated guess about which coastal state was importing coal for it. Essentially, this allowed us to develop for each state that uses imported coal, a picture of the approximate route taken by imported coal. For POL because POL consumption by state was not known, we simply assumed that the current pattern of imports would continue. Thus as the nation-wide POL port traffic is projected to increase, the fraction of traffic in each state is assumed to remain the same.

Thermal Coal

Figure 7.4-7.10 show the port traffic by state for thermal coal. The main coastal states for import of thermal coal are Gujarat, AP, Tamil Nadu and Odisha. For the coming two decades, we assume that Gujarat will import thermal coal for itself and mainly for Rajasthan, Haryana and Punjab and a small amount for MP. AP is expected to import for itself and Eastern Maharashtra; Tamil Nadu for itself and Karnataka. Odisha is not expected to use any imported coal but will import for UP, Bihar and West Bengal. Three ports on the eastern coast – one each In AP, Odisha and Tamil Nadu could serve the needs of imported thermal coal for the eastern coastal states and Bihar, West Bengal, UP and Eastern Maharashtra. On the western coast, Gujarat will need a mega port to import thermal coal. In addition, it seems that it would be appropriate to have a mega port near the Southern part of the coast of Maharashtra. This would provide imported coal for Western Maharashtra and Karnataka.

Fig 7.4 Port Traffic for Thermal Coal 2011-2012 – Base Case

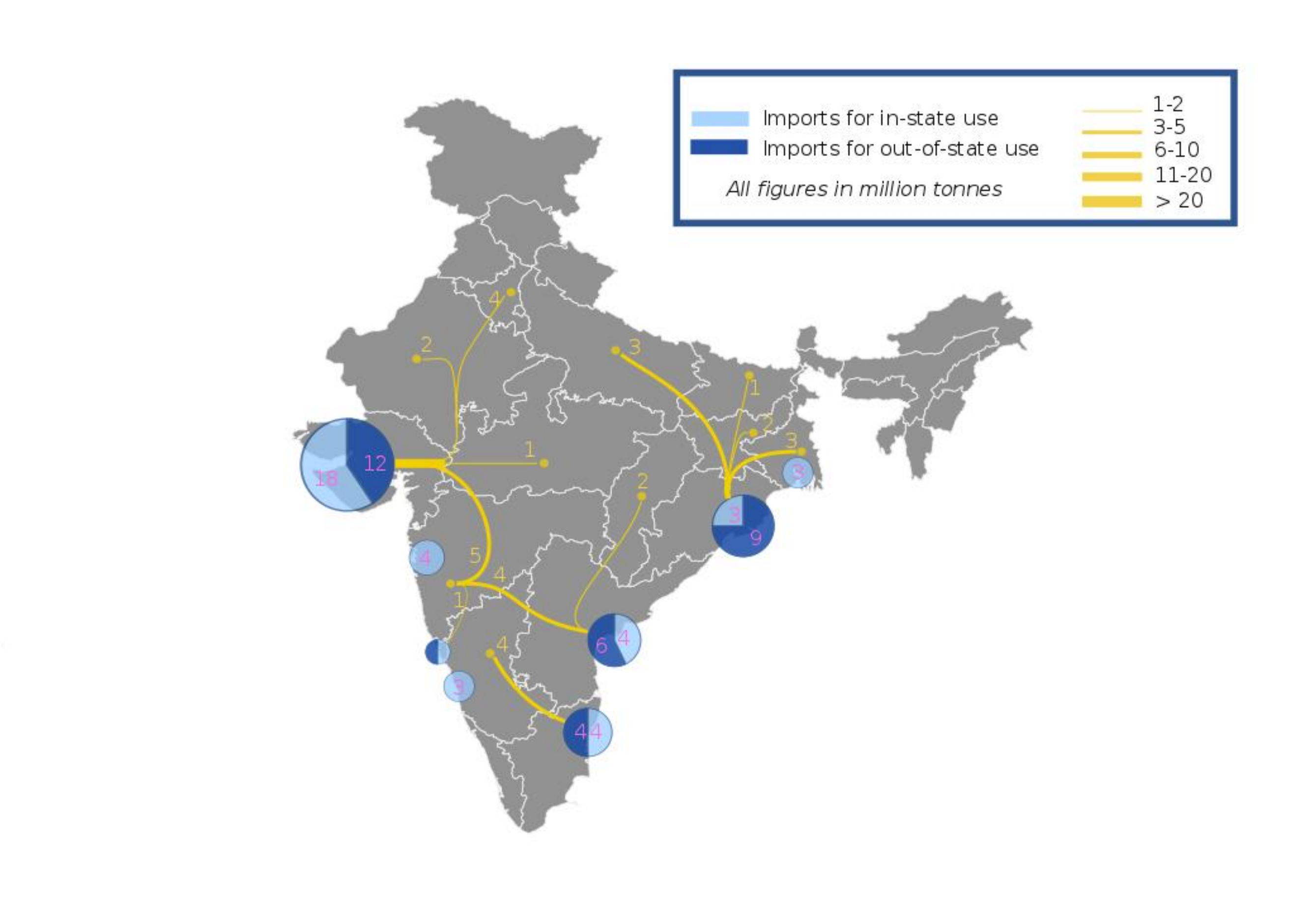


Fig 7.5 Port Traffic for Thermal Coal 2021-2022 – Base Case

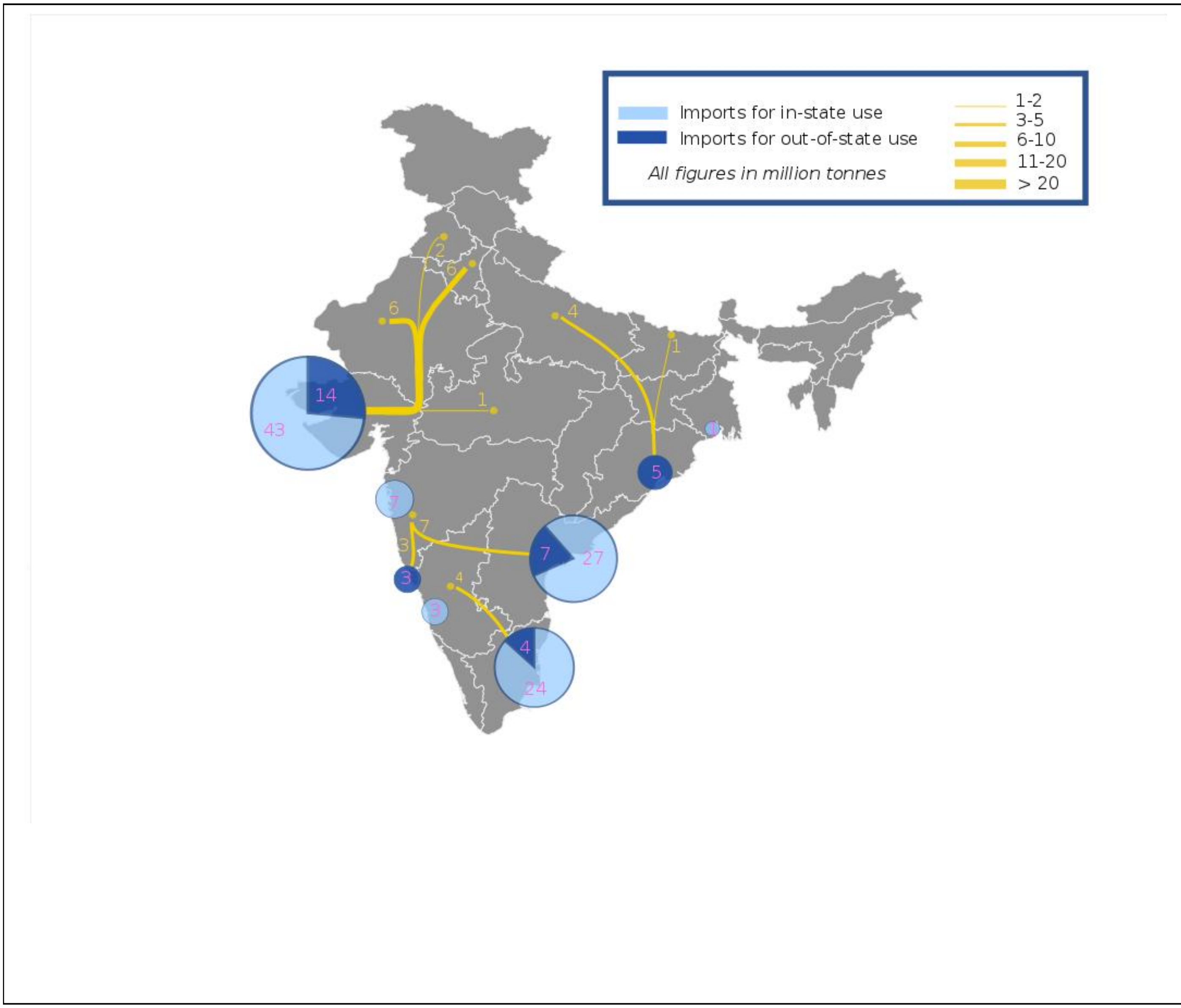


Fig 7.6 Port Traffic for Thermal Coal 2031-2032 – Base Case

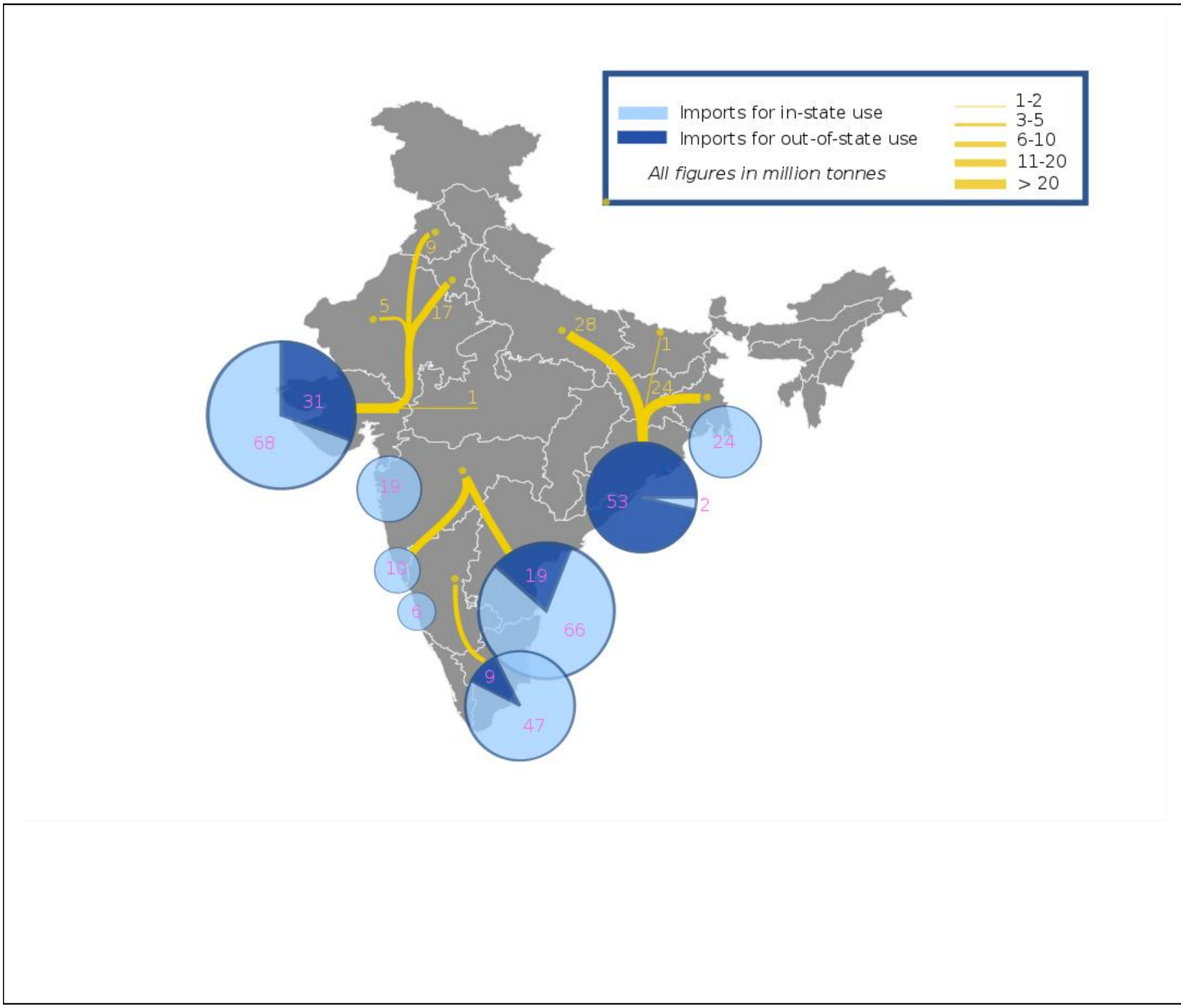


Fig 7.7 Port Traffic for Thermal Coal 2021-2022 – High Case

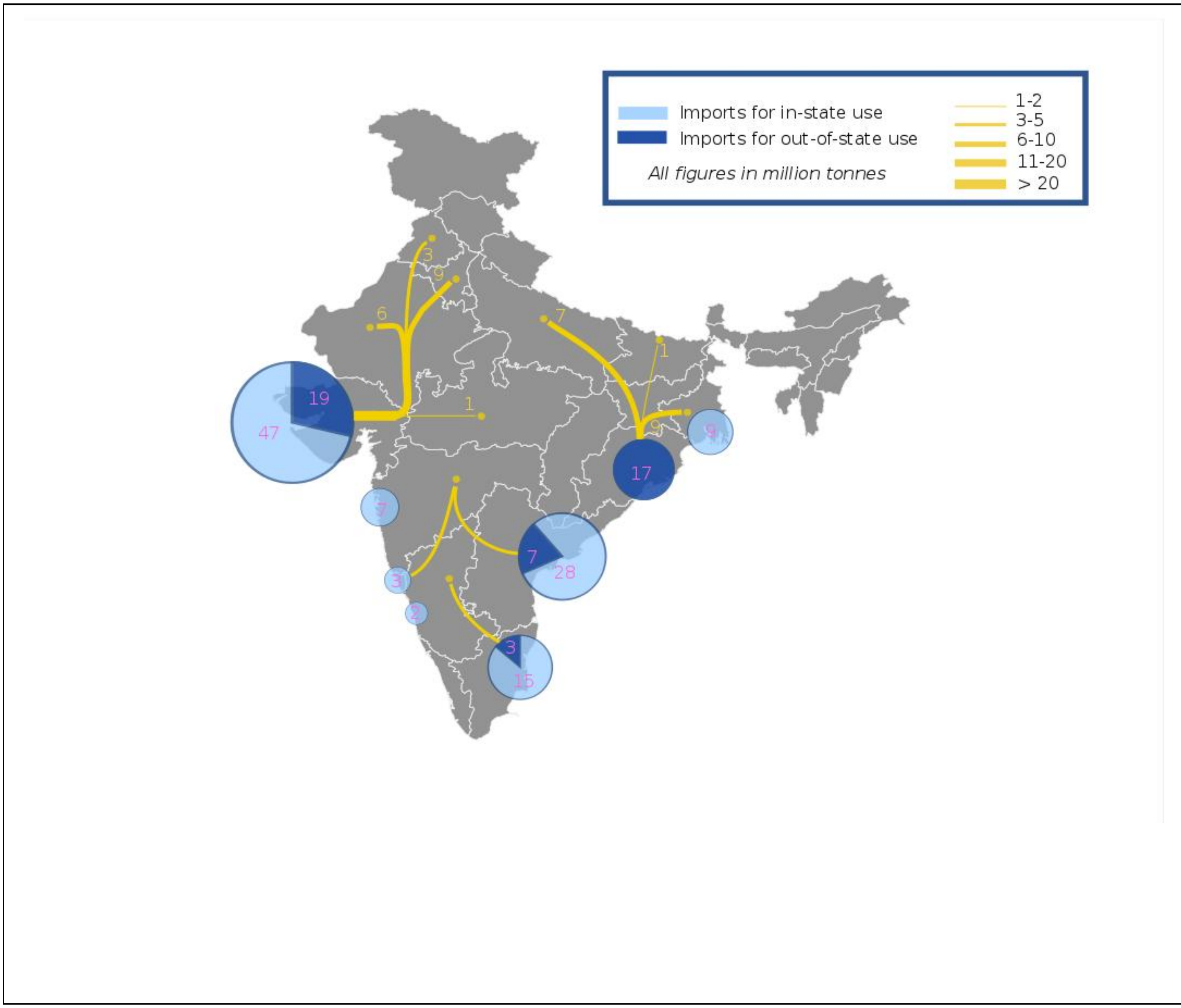


Fig 7.8 Port Traffic for Thermal Coal 2031-2032 – High Case

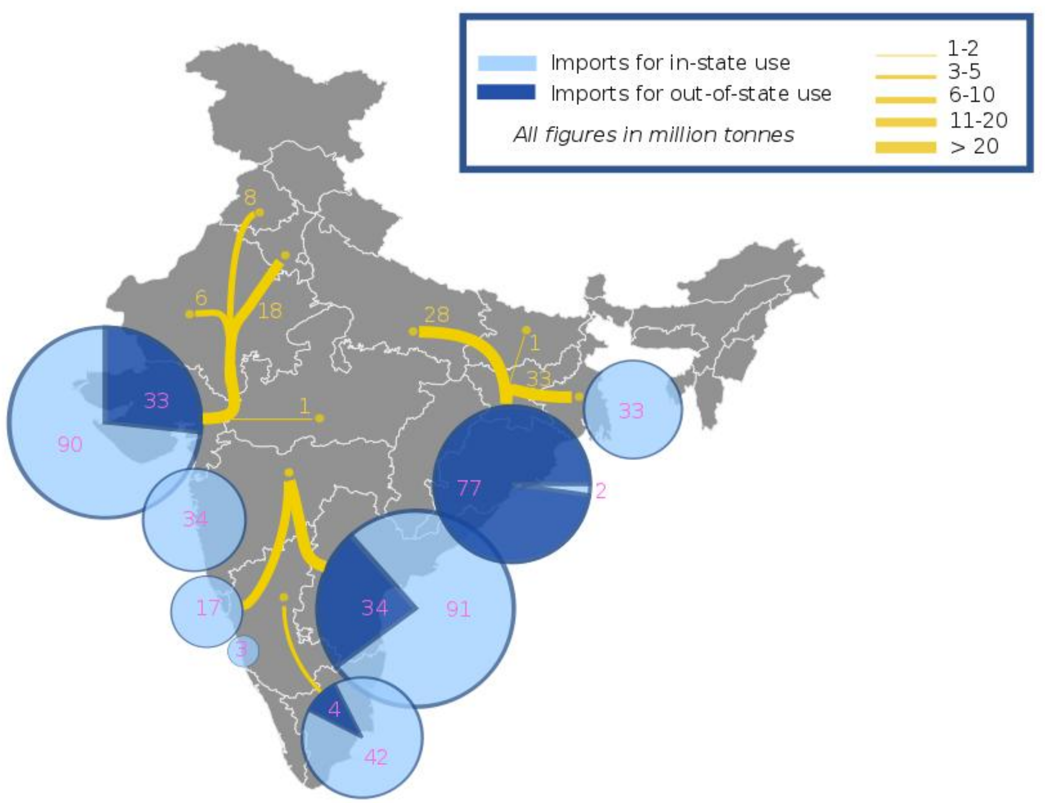


Fig 7.9 Port Traffic for Thermal Coal 2021-2022 – Low Case

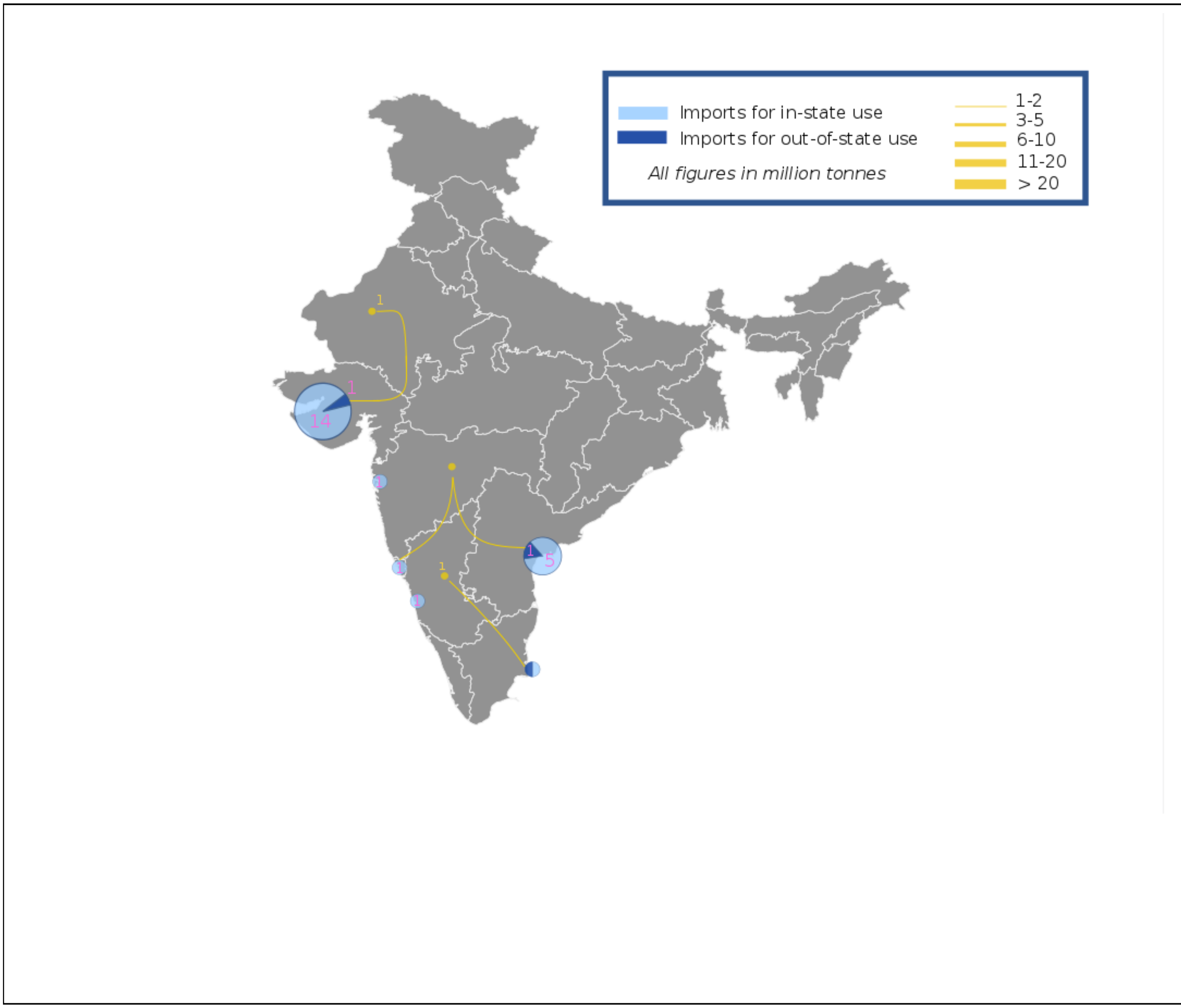
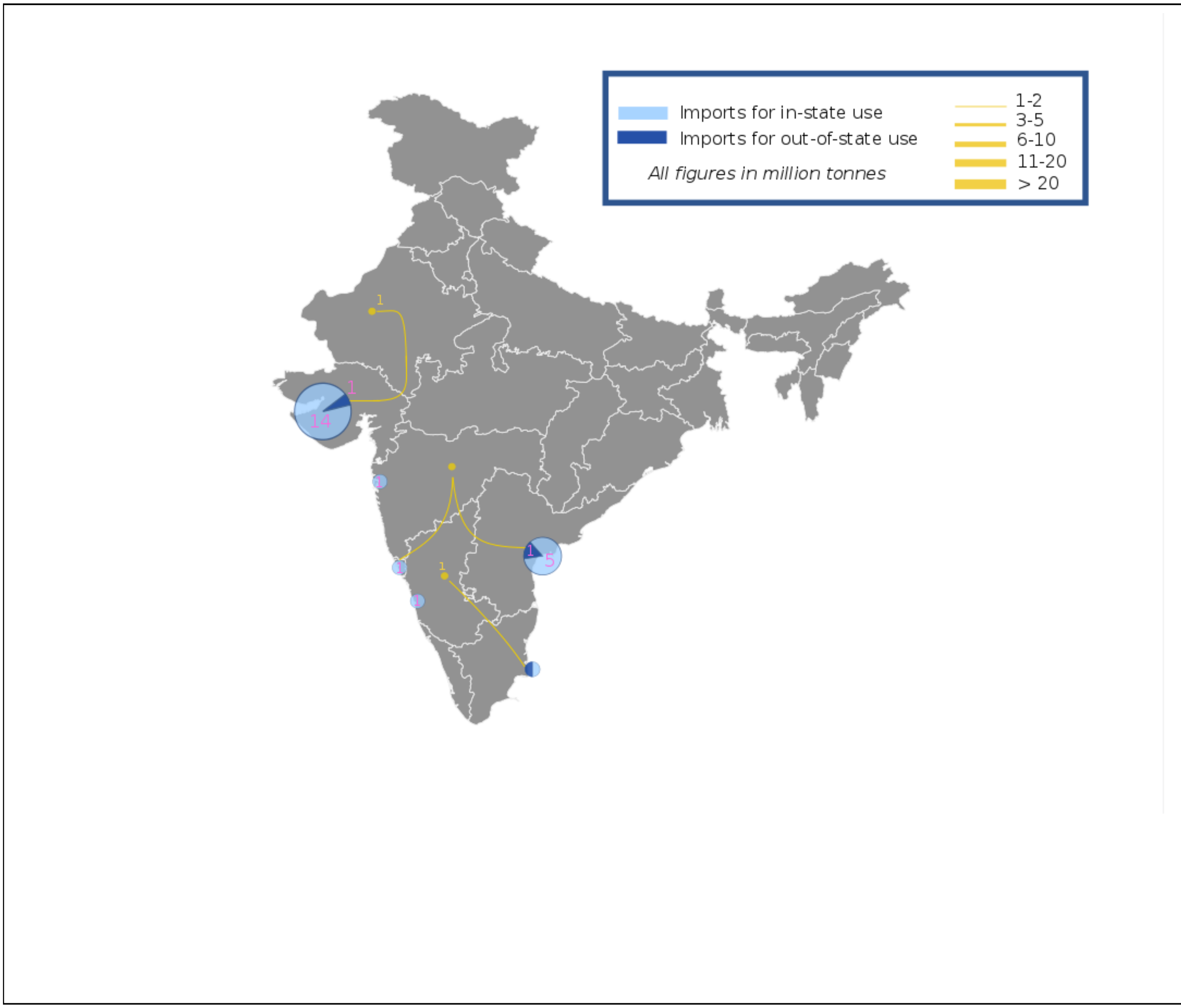


Fig 7.10 Port Traffic for Thermal Coal 2031-2032 – Low Case



Coking Coal

Figure 7.11-7.13 shows the port traffic by state for coking coal. Odisha and AP are expected to be the main ports for coking coal. Odisha will import for the steel plants in the state and for those in Jharkhand. AP will import mainly for itself and for the steel plants in Chhattisgarh. Gujarat is also expected to import a significant amount of coking coal. Karnataka and Goa are also likely to import some coal. For coking coal, mega ports in AP and Odisha would be able to serve the needs of the east coast. On the western coast, mega ports in Gujarat and the northern part of the Karnataka coast should be able to serve the need for coking coal.

Fig. 7.11 Port Traffic for Coking Coal 2011-2012

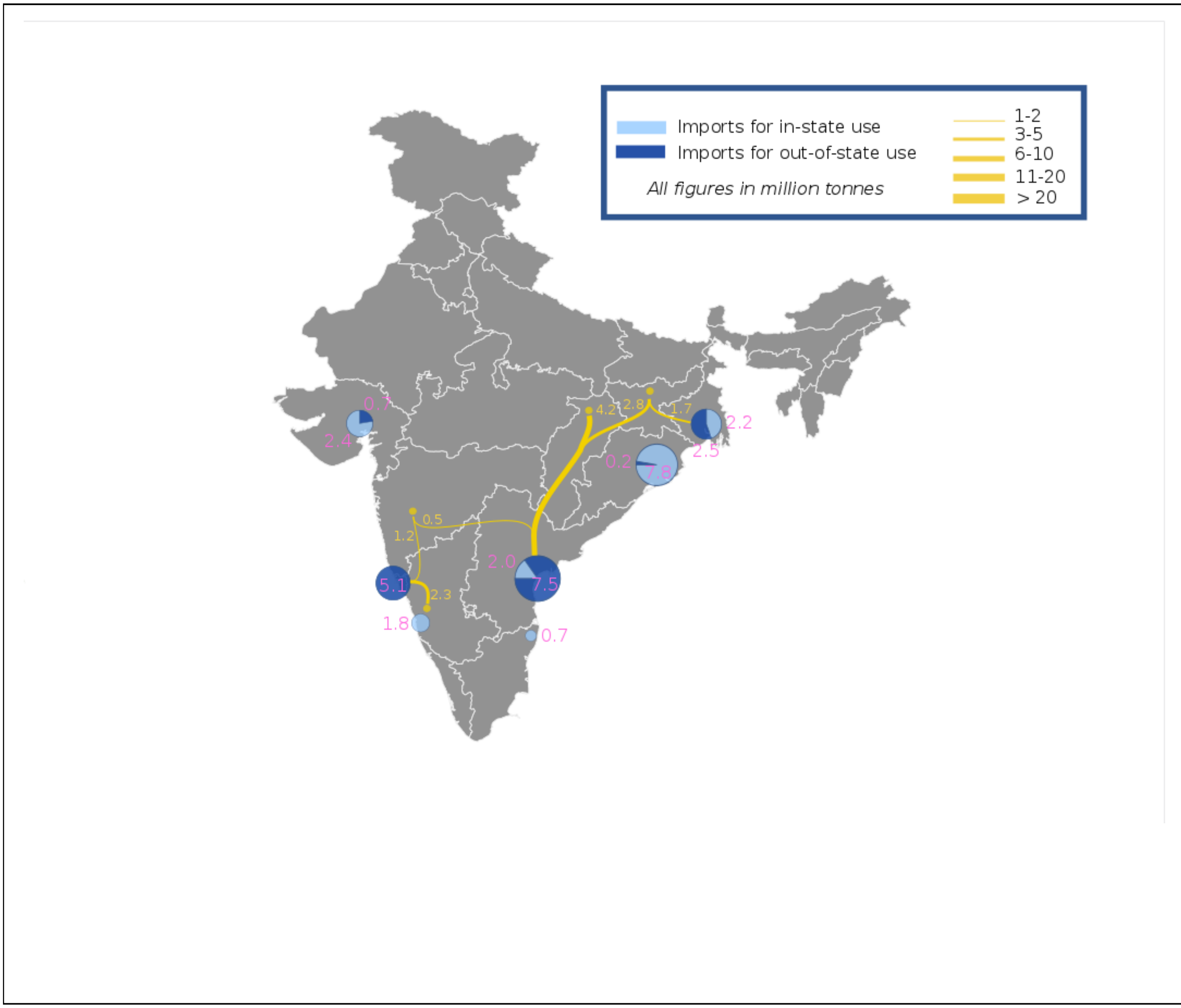


Fig. 7.12 Port Traffic for Coking Coal 2021-22

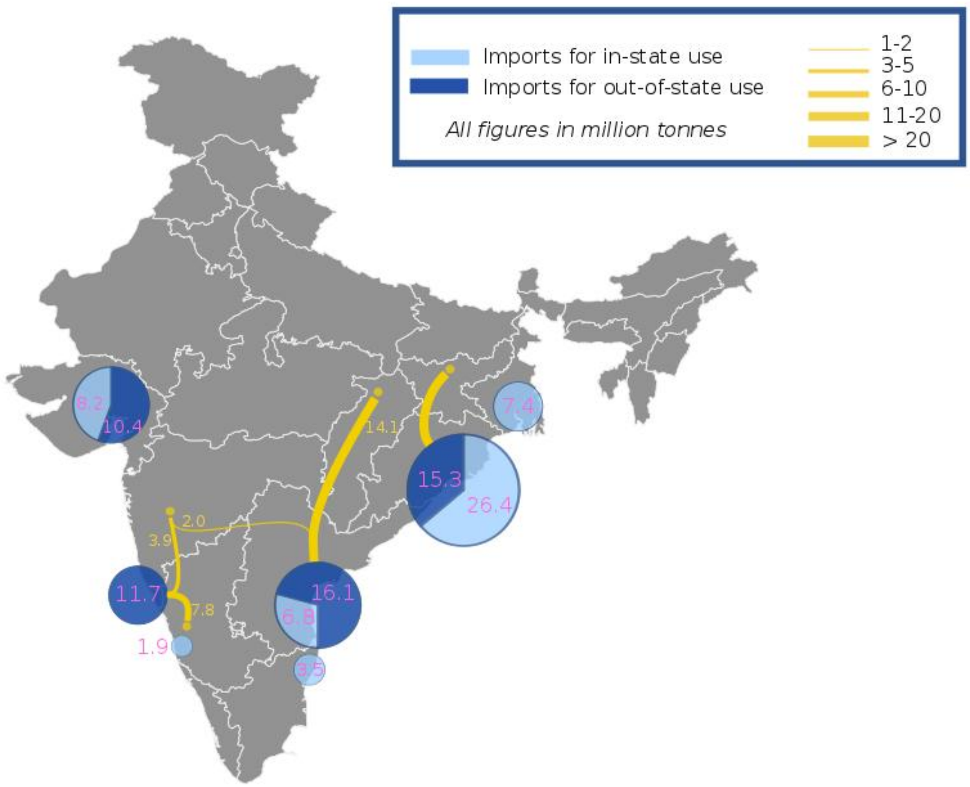
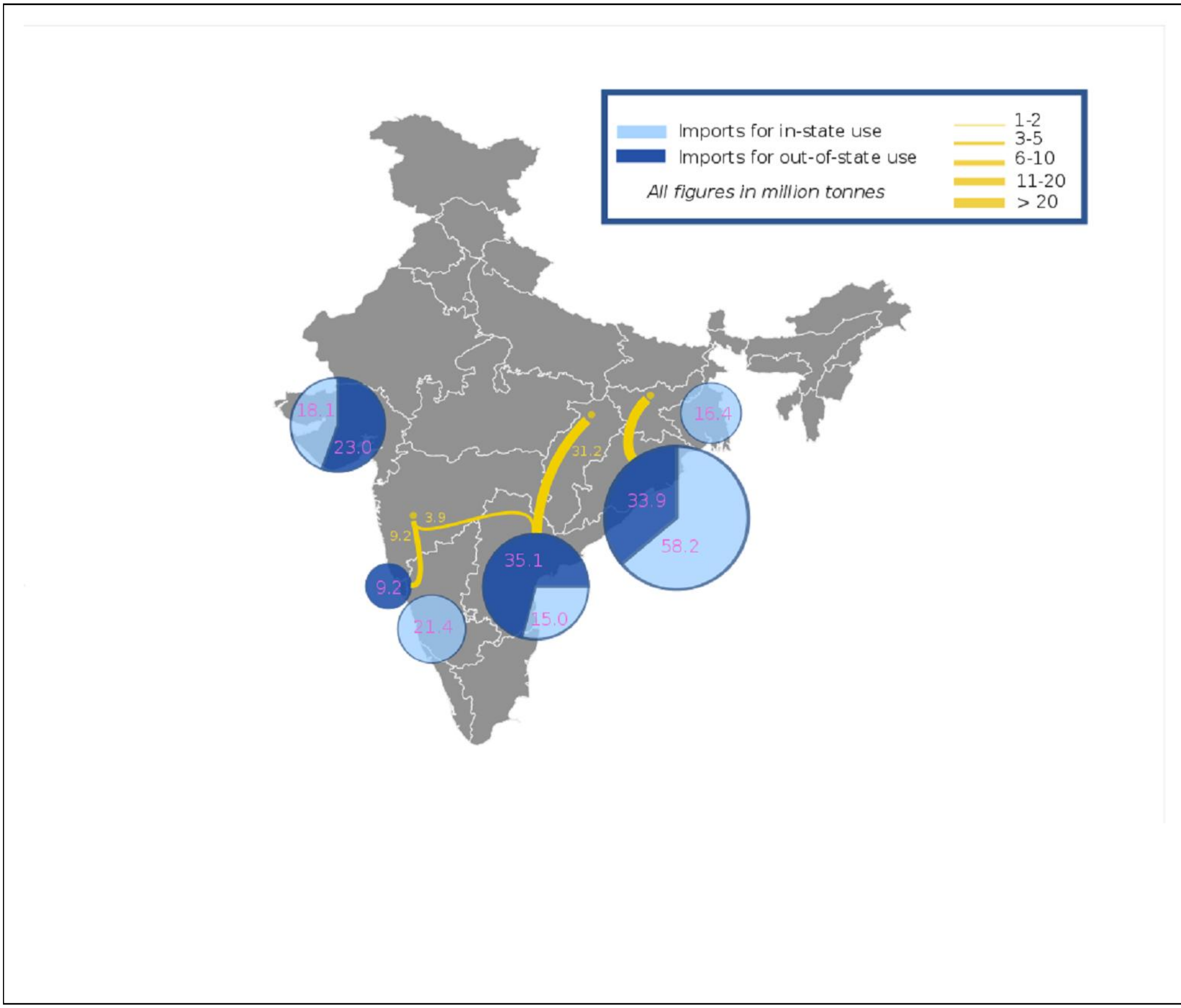


Fig. 7.13 Port Traffic for Coking Coal 2031-32



POL

Figure 7.14-7.16 shows the port traffic by state for POL. Gujarat is by far the dominant state for port traffic for POL. By 2031-32, the port traffic in Gujarat for POL is expected to reach 500 Mt. Clearly a mega port will be required in Gujarat. The other coastal states have POL traffic that is roughly equal among them but much less than Gujarat.

Fig. 7.14 Port Traffic for POL 2011-2012

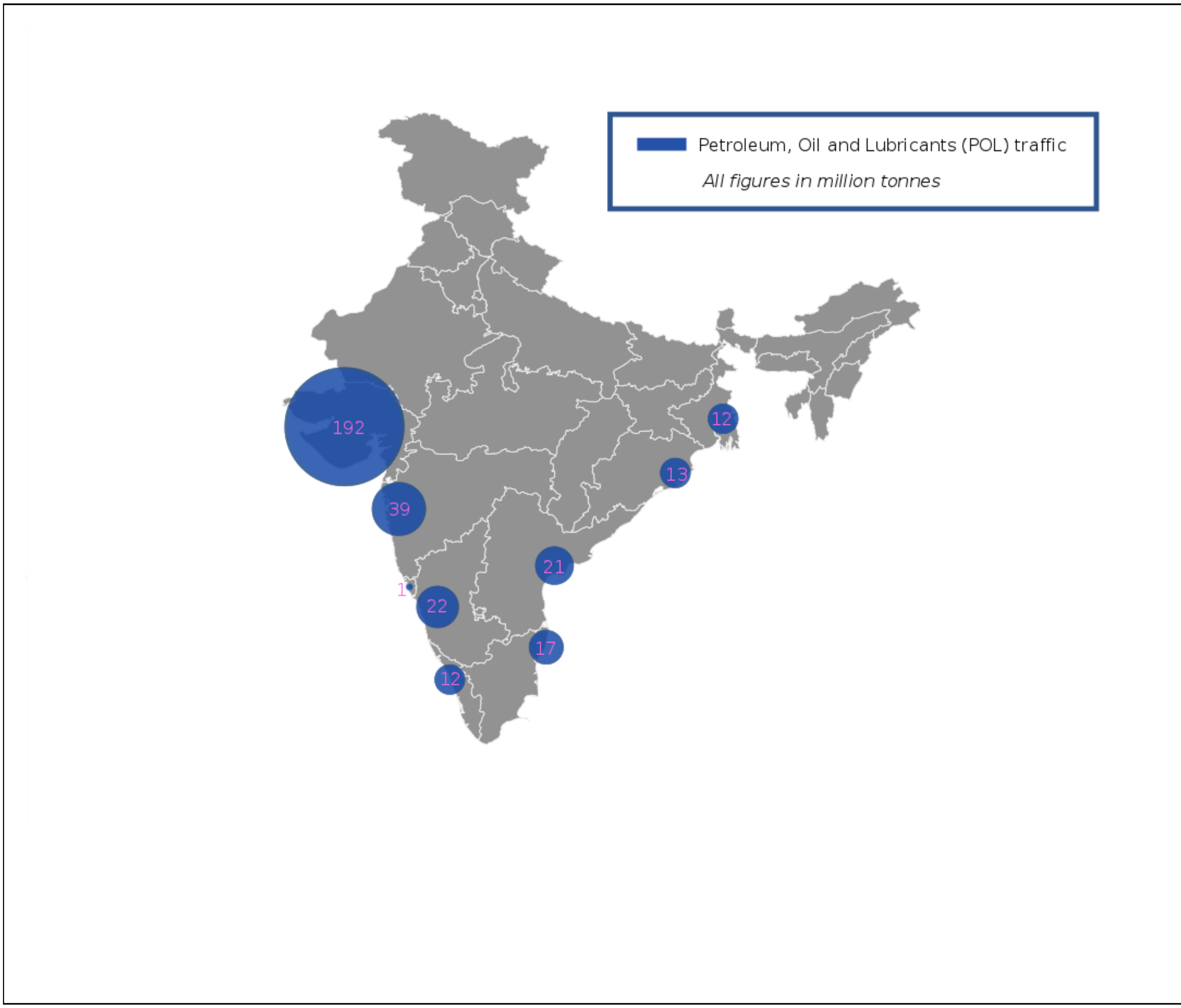


Fig. 7.15 Port Traffic for POL 2021-22

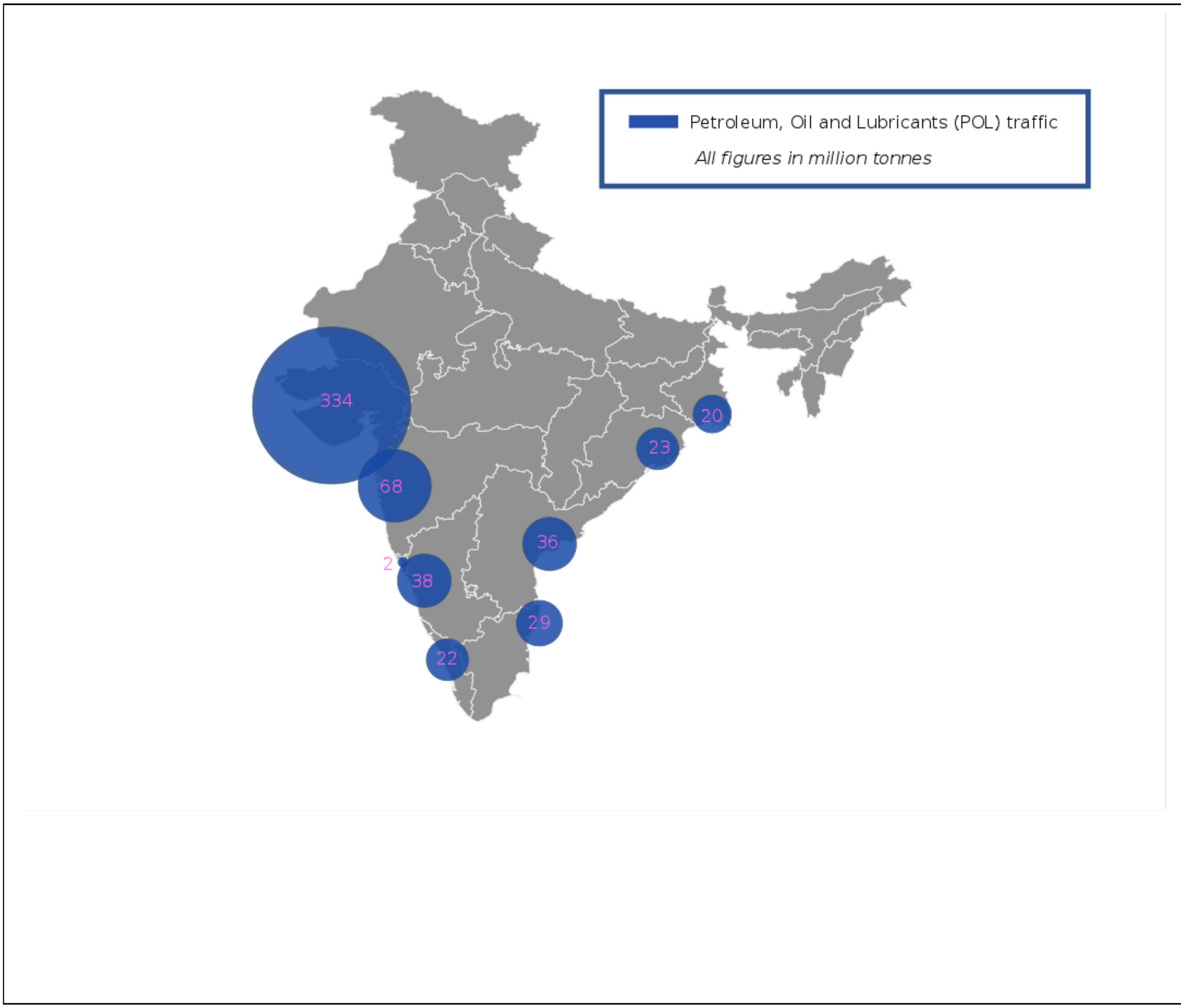
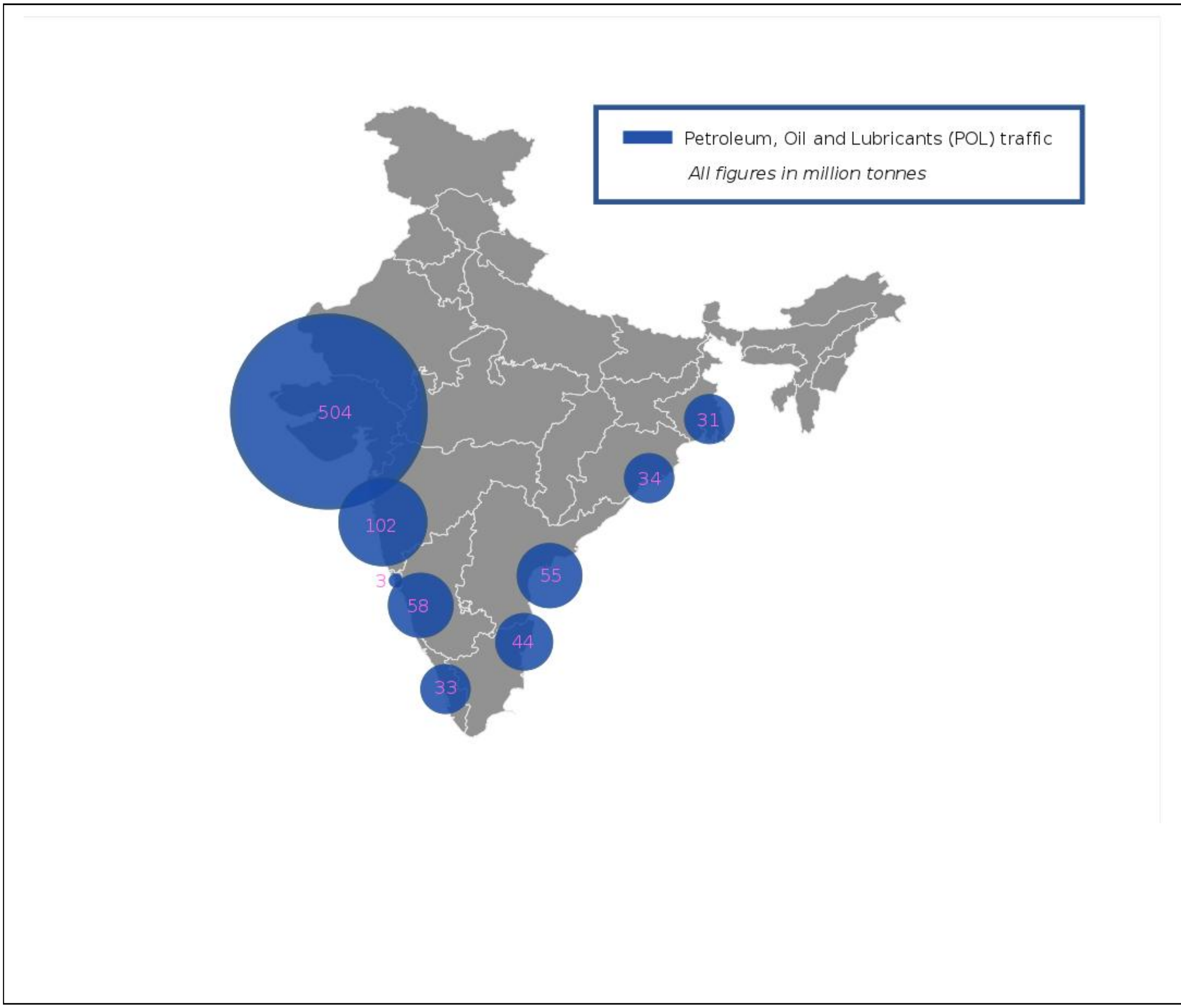


Fig. 7.16 Port Traffic for POL 2031-32



Composite Port Traffic by State

Figure 7.17-7.19 shows the composite port traffic by state due to POL, thermal coal and coking coal. Gujarat is by far the state that has the most port traffic for all three commodities, and would clearly be a prime location for a mega port. On the east coast, three states have a large amount of traffic –Odisha, AP and Tamil Nadu, and are potential candidate states for mega ports. On the west coast, in addition to Gujarat, one or two more mega ports will be required. Maharashtra has the largest amount of port traffic on the west coast after Gujarat, and it may be appropriate to have a port on the Southern end of the Maharashtra coast that could also be used to serve Gujarat and Karnataka.

Fig. 7.17 Composite Port Traffic 2011-2012

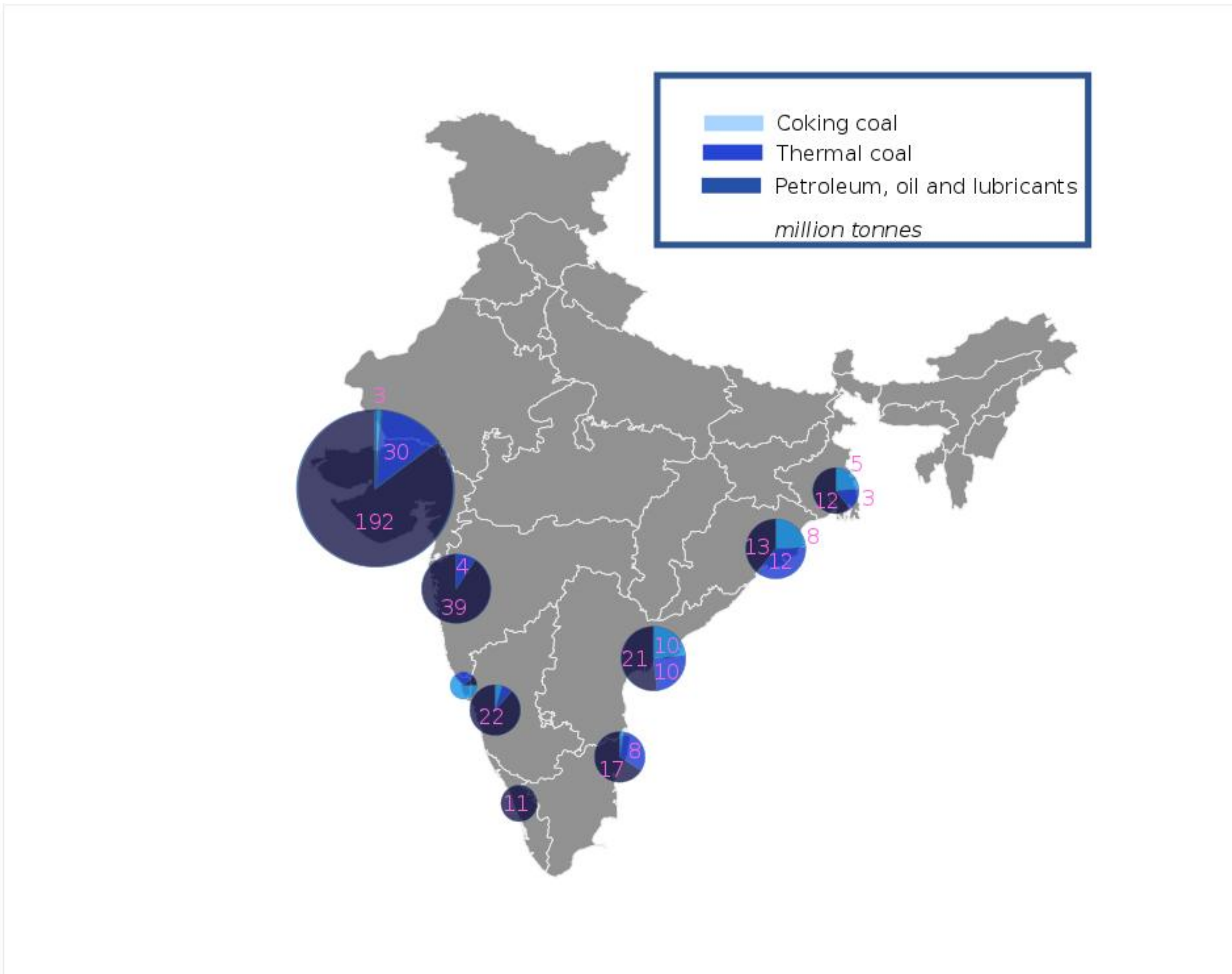


Fig. 7.18 Composite Port Traffic 2021-22

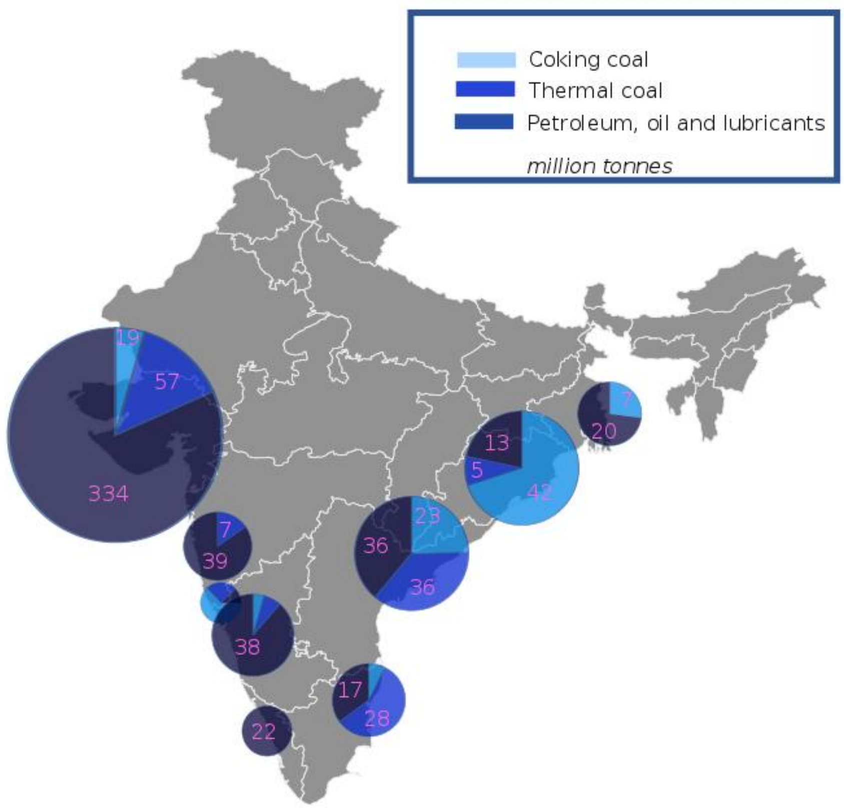
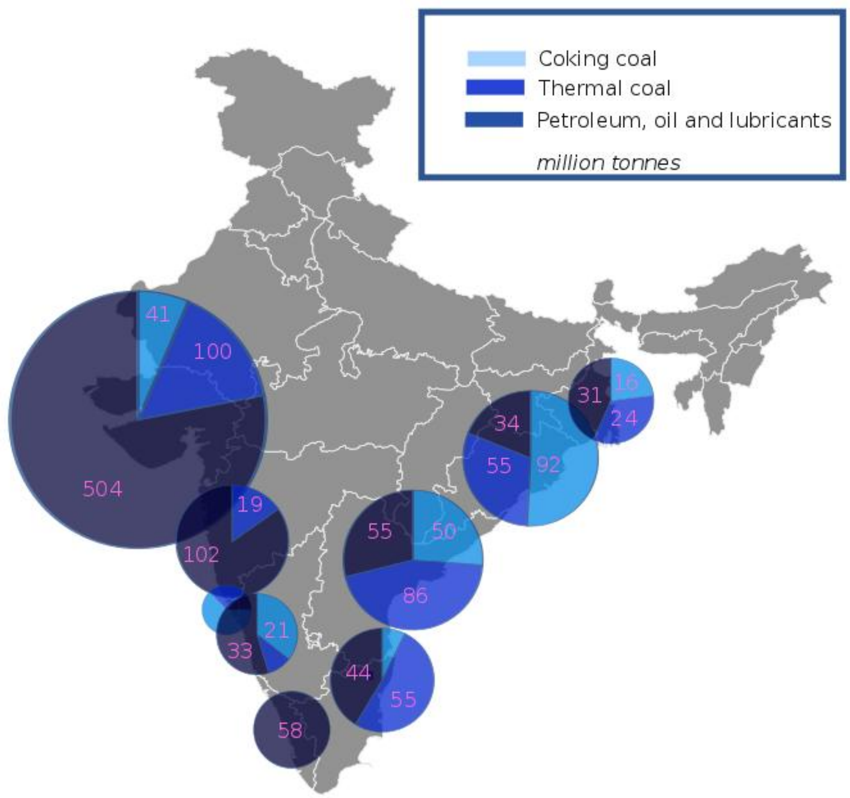


Fig. 7.19 Composite Port Traffic 2031-32



Suggestions for Locating Mega Ports

Selection of sites for locating mega ports requires extensive modeling and analysis. First and foremost, the port traffic from all commodities will need to be taken into account. In this study, we have looked at port traffic from coal and POL only. Second, detailed data are required on the cost of further development of ports at potential sites. Third, detailed modeling will be required to examine the costs and benefits of various alternative selections from a short list of potential sites.

Lack of adequate draft at the port entrance is one of the main issues that need to be addressed at a macro-level for the port sector. Except for some ports such as Mundra, Kakinada, Dhamra and Gangavaram which have a natural deep draft, most other ports have shallow natural drafts and therefore require that the depth of the approach channel be artificially created and maintained (imaritime, 2003, DPCL, 2013). Dredging is a highly capital intensive activity where the costs are very sensitive to the type of seabed that needs to be dredged. Loose sand beds are relatively cheaper to dredge but hard rock beds can be very expensive to dredge. (imaritime, 2003). These issues need to be kept in mind in strategizing about the number and location of mega ports.

In addition to the costs of creating the required draft, the investment in breakwaters also need to be considered. Breakwaters break the force of sea waves and thus create tranquil water conditions so that ships can be loaded and unloaded smoothly. However, breakwaters not only involve large investment but also have long-term effects on the sediment transport near the shore and need to be constructed only after intensive and comprehensive geo-technical studies on ocean currents in order to avoid damage to the coastline. (imaritime, 2003)

Dedicated Bulk-Handling Facilities

Except for Paradip, no major port in India has dedicated berths for unloading coal. Traditionally, this was how it was in other countries too, with bulk-cargo being handled along with general cargo in multi-purpose ports. However, now there is a world-wide trend towards development of facilities that are dedicated to handling bulk cargo. Some of the reasons for this development are (ECORYS, 2012):

- The scale of shipments and size of ships for bulk commodities have increased. Bulk cargo technologies have advanced. Larger ships require more storage space and deeper water.
- Rail connectivity up to the terminal and unit train operations have become prerequisites for bulk transport.
- In an attempt to gain control over the entire supply-chain including dedicated port facilities, shippers are looking for vertical integration.
- Urban society is becoming more conscious of environmental issues and does not want “dirty” coal and coal-dust in its neighborhoods. Furthermore, there are safety and security issues associated with commodities such as coal and POL.

The tendency towards vertical integration will need to be monitored for monopolistic practices. If a private player sets up a terminal in a port for its exclusive use and restricts entry by others or charges monopoly rents for its use, then it may distort the market for the commodity. Appropriate regulatory measures will be required to monitor and prevent such practices.

Table 7.5 gives some examples of dedicated facilities. See (ECORYS, 2012) for details.

Table 7.5 Ports with Dedicated Facilities for Dry Bulk Commodities

Country	Port	Commodity
Canada	Port Cartier	Iron Ore
	Seven Islands	Iron Ore and other minerals
	CSL Transshipment	Iron Ore, Coal
Brazil	Tubarao Terminal	Iron Ore
South Africa	Richards Bay	Coal
	Saldanha	Iron Ore and Steel
Australia	Port of Hay Point	Coal
	Dalrymple Bay Coal Terminal	Coal
	Port of Abbot Point	Coal

Source: ECORYS (2012)

Dedicated Ports/Terminals for Coastal Shipping

Ships used for coastal shipping are smaller and require appropriate berths. Major ports do not have separate berthing facilities for coastal ships. At the same time, minor ports lack adequate infrastructure and much of the equipment does not work. Consequently, turn-around times for coastal ships are high. About 70 percent of a coastal ship's time is spent in ports and only about 30 percent on voyages, inflicting huge losses on the coastal shipping companies (E&Y, 2011). It is suggested that several minor ports be developed along the coast every 100-200 km with the following capacity (E&Y, 2011):

- Ability to handle vessels with a requirement of draft up to 5 meters.
- Material handling and other infrastructure to turn around a vessel in 12-18 hours.
- Sufficient first and last mile connectivity to road/rail network.

This will reduce congestion at major ports and enhance the efficiency of coastal shipping.

Connectivity to Ports

Ports should be seen as nodes in the transport network and not a goal in themselves. As far as bulk commodities are concerned, port connectivity is essential for the import of both thermal and coking coal. In 2005, a Committee of Secretaries was set up to establish policies to improve port connectivity. The Committee recommended that each major port should be connected by at a minimum a four lane road and double line rail. Because imported coal is most likely to be transported by rail, we focus only on rail connectivity here.

While Kolkata, Haldia, Vizag, Ennore, Chennai, Tuticorin, have the required double line connectivity, for the following ports the provision of double line connectivity is in progress:

- Paradip port is connected by a double line section with Cuttack to the Howrah-Chennai trunk line. The Daitari-Banspani and Haridaspur-Paradip lines are under construction.
- Cochin port has single line connectivity and is in the process of getting double-line connectivity
- New Mangalore port has limited rail connectivity and additional connectivity needs to be provided.
- Mumbai Port has double line connectivity but the trains have to pass through a busy suburban section. Work on a third line is in progress.
- Kandla port has connectivity to Mumbai and Delhi via Ahmedabad. Doubling of the Gandhidham-Kandla is in progress.

Connectivity to the non-major ports is pathetic. Of the 176 non-major ports, only 60-65 ports are active and handling import and export of cargo. Of these 60-65 ports, only six have rail connectivity up to the port. Another 8-10 have a railway station nearby but still need last mile connectivity to the port. Provision of rail connectivity to the non-major ports needs to be improved urgently.

Investment for Upgrading Ports

The estimates of investment required in ports for bulk commodities are based on the volume of import/export traffic for coal and POL. We have considered coal and POL only so that we can estimate how much investment can be attributed to these bulk commodities; however, we recognize that actual planning and investment would consider all commodities and would take into account any synergies between the various commodities. Further, these estimates are indicative only and are not based on detailed planning. Such detailed planning would be premature anyway because a detailed strategy for ports needs to be developed first taking account some of the considerations that we outlined earlier.

The calculation of the required investment levels is shown in Table 7.6 below. It starts with estimates of traffic for (1) import of thermal coal; (2) import of coking coal; and (3) POL import of crude oil and import and export of petroleum products. In order to minimize delays, international practice requires that cargo handling capacity at ports be 30 percent more than the anticipated traffic (MoShipping, 2012). Required capacity in Table 7.6 is calculated on that basis. In order to calculate the cost of creating capacity, estimates of 55 crores/Mt of additional capacity for coal and 52 crores/Mt for POL have been used. These estimates have been suggested in the WG report and are based on calculations by TAMP of the cost of adding capacity. Lastly, 100 percent has been added to these costs for additional facilities and activities such as deepening and maintenance of channels and other infrastructure. These calculations indicate that about Rs 140,000 crores would be required over the next two decades to support the required import/export of coal and POL.

Table 7.6 Investment Required in Ports for Coal and POL

	2011-12	2016-17	2021-22	2026-27	2031-32
Traffic (Mt)					
Thermal Coal	48	88	138	266	356
Coking Coal	30	65	108	173	238
POL	334	490	596	725	816
Capacity (Mt)					
Thermal Coal	62	114	179	346	463
Coking Coal	39	85	140	225	309
POL	434	637	775	943	1,061
Incremental Capacity Reqd (Mt)					
Thermal Coal		52	65	166	117
Coking Coal		46	56	85	85
POL		203	138	168	118
Cost of Creating Capacity (Rs crores)					
Thermal Coal		2,860	3,575	9,152	6,435
Coking Coal		2,503	3,075	4,648	4,648
POL		10,546	7,166	8,720	6,152
Total		15,908	13,815	22,520	17,234
Cost of Other Facilities		15,908	13,815	22,520	17,234
Total Investment required		31,816	27,630	45,040	34,468
Total Cumulative Investment 2012-2032 (Rs Crores)					1,38,954

Source: Ministry of Shipping and Working Group Research (2012)

Summary

Port traffic for bulk commodities (POL and coal) is expected to grow by 3-3.5 times over the next two decades. Our ports are already stretched to capacity. Capacity utilization at major ports averages around 85 percent with at least four ports operating at an utilization of 100 percent or more. International norms recommend capacity utilization be below 70 percent to avoid delays. As a result, performance of ports is very poor. There is no concept of "pre-berthing detention" as such in world class ports, while on average ships have to wait for more than 2 days to get a berth at an Indian port.

There are several reasons for the poor performance: (1) low level of mechanization; (2) inadequate cargo handling equipment; (3) inadequate navigational aids and facilities; (4)

insufficient use of information technology; and (5) insufficient drafts which means that larger ships cannot load and unload at the ports; (6) insufficient storage space.

Efforts are being made to improve performance of ports but they are mostly focused on improving the performance of individual ports. A broader and coherent strategy needs to be developed for the overall ports sector based on a vision for the sector.

Mega ports provide very significant economies of scale and most of the world's major economies have a few mega ports. However, India has none. The number and location of mega ports needs to be based on balancing the costs of developing these ports with the returns on investment based on estimates of port traffic. An assessment of the expected traffic at ports over the next two decades reveals that four coastal states are expected to have most of the port traffic of bulk commodities – Gujarat, AP, Odisha, and Tamil Nadu and could be potential candidate states for mega ports. In each of the four states, there is an existing port that has a deep draft and could be developed to become a mega port: Mundra (Gujarat); Gangavaram (AP); Dhamra (Odisha); and Ennore[8] (TN).

However, selection of sites for locating mega ports will require extensive modeling and analysis. First, all types of port traffic including containers and other commodities needs to be included in the analysis. Second detailed data are required on the cost of development of candidate ports, and then detailed modeling is required to examine the costs and benefits of various alternative selections from a short list of potential sites.

[8] While Ennore has a draft of only 16 meters and the requirement for Cape Size vessels is 18 meters, the soil there consists of sand and soft to medium clay and silt. Therefore, dredging costs are expected to be low.

Chapter 8. Conclusions and Recommendations

Economic growth is critically dependent on adequate amounts of electric power and steel. Almost all economic activity requires electricity, and steel is an important input for many industries. In order to sustain a GDP growth rate of 8 to 9 percent over the next two decades, it is estimated the production of electrical energy will need to increase by 3.5 times from 1,105 BU now to 3,860 BU by 2031-32. Because coal is expected to remain the dominant fuel for the power sector, the requirement for coal is expected to grow correspondingly. The use of domestic coal for the power industry will be limited by the amount that will be produced and is expected to grow by about 2.5 times; from about 440 Mt in 2011-12 to 1,110 Mt in 2031-32. Imports of coal for the power sector will bridge the deficit and will grow much faster; by almost 5 times; from 73 Mt in 2011-12 to 355 Mt by 2031-32.

The intensity of steel use in the economy is expected to increase, and therefore, requirements for steel will grow faster than the growth of the economy from 73 Mt in 2011-12 to 495 Mt in 2031-32; almost an eight-fold increase. Keeping in mind that a tonne of finished steel requires 3-4 tonnes of raw materials, the transport requirements for the steel industry will be huge; growing from 600 Mt in 2011-12 to about 2230 Mt in 2031-32.

Clearly India's requirements for bulk commodities are expected to grow rapidly over the next two decades. The transport requirements for the power and steel industry are expected to grow from about 900 Mt now to 3,700 Mt in 2031-32. While POL and natural gas will also grow, most of the transport for these commodities will be carried out through pipelines. Some POL will be transported by rail but the volumes will be very small and are not expected to have much of an impact on the rail network. However, POL will have a huge impact on cargo traffic at ports. Already POL has the largest share (38 percent) of port traffic, and POL related traffic is expected to increase by more than 2.5 times from about 330 Mt in 2011-12 to 865 Mt in 2031-32.

These very large increases in the transport requirements for bulk commodities over the next two decades would be a challenge under any circumstances. For India the challenge is even bigger because our transport systems for bulk commodities are barely able to cope with the traffic today. The trunk railway network is heavily congested. Generally, a rail route is considered congested when the capacity utilization increases beyond 80 percent. Almost all the the major rail routes[9] over which coal and iron ore will be transported are operating above 100

[9] Overall in the country, about 40 percent of the sections are operating at 100 percent or higher of capacity. Another 20 percent are operating between 80 and 100 percent capacity. The sections making up the high density routes fall predominantly in the first category. Therefore, high density routes on which coal and iron ore is transported are almost all congested.

percent of capacity. Build up of coal stocks at pit-heads is an early warning of the lack of capacity in the transport system to meet increased traffic.

Similarly, Indian ports are stretched to capacity. The capacity utilization averages 85 percent with at least four operating at a utilization level of 100 percent or more. International norms recommend that capacity utilization of ports be below 70 percent to avoid delays.

Unless well-planned steps to rapidly improve the bulk transport system are successfully implemented, the transport system will become a stranglehold on the economy starving it of energy materials and other key commodities that are essential for economic growth.

Rail Network

Coal and iron ore are brought mostly by road from mines to the rail sidings. Feeder routes then carry the coal or iron ore from the rail sidings to the trunk routes. The trunk routes carry the minerals long distances, usually between distant states. Close to the destination, feeder routes move the materials from the trunk route to the rail siding at the power or steel plant. Not all shipments of coal or iron ore traverse all these segments. For example, thermal coal destined for a power plant within the coal producing state is likely to be moved over a single feeder route between the mine and the power plant. The transport requirements can be quite different depending on the types of rail segments traversed. Coal transported to plants within the coal producing region will rely mostly on MGR, conveyor belts/ropes and short rail routes. Such short rail routes within coal producing regions may use a short part of a DFC, but will not make extensive use of DFCs. On the other hand, transport to distant states is likely to make extensive use of routes covered by DFCs. As the economy grows, domestic coal will be used “closer to home” and therefore, the importance of shorter rail routes will increase. Furthermore, the rate of growth of the economy will affect the relative importance of short rail routes versus DFCs, highlighting the importance of adaptability of plans for bulk transport.

Critical Feeder Routes at Mines

Most of the increase in coal production is expected to come from three regions: (1) Talcher and Ib Valley coalfields in Odisha with a potential increase of 110 Mtpa by 2031-32; (2) North Karanpura coalfields in Jharkhand with an increase of 75 Mtpa; and (3) Mand-Raigad coalfields in Chhattisgarh with an increase of 90 Mtpa. Feeder routes that will carry coal from the mine to the trunk routes are critical to bring the coal to power plants and steel plants. But eight critical feeder routes in these regions are awaiting completion (please see Table 6.4). Shortages of coal which are already slowing down the economy will become even more acute in the future if these feeder routes are not completed. Similarly, critical feeder routes for moving iron ore must be completed to ensure steel production keeps up with the economy’s requirements. Critical feeder routes for the steel industry are listed in Table 6.5. ***The total cost of these routes will be about Rs 3,500 crore for coal and Rs. 11,740 crore for steel; just 2.4 percent of the Railways***

budget for the 12th Five Year Plan, but with large benefits for the economy. These critical routes must be completed on the highest priority within the 12th Five Year Plan.

Importance of Short Distance Transport of Coal

As the economy grows, domestic coal will be used closer to home. Consumption of coal within coal producing states is expected to increase from 44 percent currently to 60 percent by 2031-32. If we include transport of coal to neighboring states, we find that about 70 percent of domestic coal in 2031-32 will be used within coal producing regions. As a result, a very large portion of domestic coal will not make extensive use of DFCs, even though some transport within coal producing regions may occur over short sections of DFCs. Similarly, more than 80 percent of the imported coal will be used by coastal states. ***Under these circumstances where a progressively greater share of coal will used within the source and coastal states, it is expected that the share of short rail routes, road, MGR and conveyor belts or ropes will grow. Therefore, attention must be focused on these modes of transporting coal to ensure that the power sector does not suffer from insufficient supply of coal.***

Feeder Routes to Power Plants within Coal Producing States

As in-state consumption of coal for power is likely to increase, much of this new capacity will come up in clusters of about 3,000-4,000 MW each. Because such power plants will need to be located not only near coal mines but also near sources of water, it is difficult to predict where these clusters of power plants will be located. In any case, feeder routes from the mines to the power plants will need to be provided. We estimate that such links will be about 70-100 km long and will be required to carry about 20 Mtpa each. ***Therefore, roughly one such feeder route to a cluster of power plants will be required every year in the tri-state region of Odisha, Jharkhand and Chattisgarh***. These links should be designed for heavy haul technology where a rake per day carries 4 Mtpa. It is likely that some of these feeder routes may overlap to some extent, with each other or the feeder routes that bring coal from the mine to the trunk route. ***Because each such feeder route will take a minimum of six years to complete, planning for these routes must be coordinated with investments being planned in the power sector, and decisions for the corresponding transport investment should be taken simultaneously.***

Construction of DFCs

Even though domestic coal will be used closer to home, transport to distant states will also increase. From the perspective of transport of bulk commodities, some of the DFCs may be more important than others for this long distance transport. The Eastern DFC is likely to carry an overwhelming share of the long distance coal traffic, with its share increasing from about half currently to about two-thirds by 2031-32. Excluding the Southern DFC, the other DFCs have a much smaller and about equal share of the long distance coal traffic. The Southern DFC is not expected to carry much coal. Therefore, ***the Eastern DFC must be given the highest priority among the DFCs, and should be completed within the 12th Five Year Plan. The Western, East-West, North-South and East Coast DFCs should be completed by the end of the 13th Plan, and***

the Southern DFC can be completed by the end of the 15th Plan. For all the DFCs that have one termination point in the eastern resource-rich part of the country, construction must start from there because bulk traffic is the highest in those areas. Furthermore, some of the consumption within coal producing states may use short sections of DFCs, so transport within coal producing states will also be facilitated.

Adaptive Planning and Coordination between Ministries

A counter-intuitive result from the model of the power sector is that under the low growth scenario the movement of domestic coal is larger putting even more pressure on the rail freight system. This is because as growth slows, domestic coal will not required to the same extent closer to the producing area and will be available to be sent to areas further away, thus reducing imports of coal. This will increase the burden on the rail transport system, unfortunately right when public resources are likely to be more constrained. The results from the modeling exercise also show that there can be great variation in both the amount of coal to be transported and the pattern of the movement, triggered by changes in the rate at which the economy is growing, greater use of renewables, increased availability of gas or higher energy efficiency.

Given this uncertainty, it is important that planning for bulk transport of energy commodities be adaptive. A strategic bulk transport planning group should be established that monitors developments and potential developments in coal and other fuel markets, renewable energy technologies, and domestic fuel supply. In response to changing conditions it should periodically (say every five years) direct changes in the plans for transport of fuels so that adequate fuel supplies are available to power plants without delay and at low cost. The group should include all major stakeholders and representatives from power, railways, and natural gas sectors.

In a working paper on *Institutions for Transport System Governance* done for NTDPC, it has been proposed that an Office of Transport Strategy (OTS) that would integrate transport planning across modes and coordinate between the Ministries and other levels of government. Two options are proposed for locating OTS: (1) creating a new entity linked to the Prime Minister's Office (PMO) or the Cabinet Secretariat; or (2) restructuring the Planning Commission Transport Division for this purpose. The strategic bulk transport planning group could be established under OTS and OTS could extend coordination to non-transport Ministries such as power, petroleum and natural gas, and steel on issues related to transport of bulk commodities.

Modernization of Equipment

Freight transport in India is far less efficient than rail in other countries. There is a great need for upgrading and modernizing equipment, rolling stock and rail lines. As the Railways recognizes, trains must be heavier, longer and faster in order to maximize the use of existing infrastructure**.** Heavy haul technology should be used wherever possible and new lines should be designed for it. It increases the capacity of trains about four-fold so that a train per day that results in transport of about one Mtpa using current technology would result in transport of 4 Mtpa.

Bulk Transport Related Investment Required in the Rail Network

Suggested plan-wise investments are given in Table 6.8 repeated below for convenience. These investments in the rail network have been prioritized on two characteristics: (1) level of impact of the investment; and (2) urgency of the route development. Total investment of about Rs 670,000 crore over the twenty-year period will be required. The investment is relatively higher in the 12th and 13th Plan when most of the major investments will be made.

Table 6.8 Suggested Plan-Wise Investment for Railways (Rs Crore)

Category of Investment	12th Plan	13th Plan	14th Plan	15th Plan
Critical Feeder Routes - Coal	3,150			
Critical Feeder Routes - Iron and Steel	11,740			
Feeder Routes for Power Plant Clusters	1,500	1,500	1,500	1,500
Eastern DFC	45,975			
Western DFC	26,845	11,505		
E-W DFC	16,467	32,933		
East Coast DFC	9,142	18,283		
N-S DFC	18,250	36,500		
Southern DFC			11,275	11,275
Additional Augmentation		48,185	48,185	48,185
Rolling Stock and Terminals	44,138	66,300	74,850	80,550
TOTAL	177,207	215,206	135,810	141,510

Source: Working Group Research

Ports

As discussed earlier, by 2031-32, Indian ports will have to handle five times more thermal coal than today, 7.5 times more coking coal, and about 3.5 times more POL. Indian ports are barely able to handle current levels of imports and so handling these large increases in the future will be a big challenge. There are several reasons for the poor performance of Indian ports: (1) insufficient drafts; (2) low level of mechanization and inadequate cargo handling equipment; (3) inadequate navigational aids and facilities; (4) insufficient use of information technology; and (5) insufficient storage space.

Need for a Vision for the Ports Sector

Efforts are being made to improve the performance of ports; however, they are focused on improving the performance of individual ports while improvements need to be made on a system-wide basis. From the perspective of port requirements for bulk commodities, a vision needs to be developed for the ports sector and a national strategy developed based on it. One issue is the establishment of mega ports because they provide very significant economies of scale and most of the world's major economies have a few mega ports. India has none.   Mega ports can accomodate larger ships resulting in a reduction of up to 40 percent of transport costs. In addition, mega ports provide very signficant economies of scale for advanced handling equipment which can dramatically reduce turn-around times for vessels. A vision for the ports sector should consider issues such as: How many mega ports should there be in the country and where should they be located. What will be the roles of mega ports, major ports and non-major ports in such a framework? What role should coastal shipping play in the framework?

Selection of Sites for Mega Ports

An analysis of the expected port traffic from POL and coal over the next two decades reveals that Gujarat is by far the state that has the most port traffic for all three commodities, and would clearly be a prime location for a mega port. On the east coast, three states have a large amount of traffic -Odisha, AP and Tamil Nadu, and are potential candidate states for mega ports. On the west coast, in addition to Gujarat, one or two more mega ports will be required. Maharashtra has the largest amount of port traffic on the west coast after Gujarat, and it may be appropriate to have a port on the Southern end of the Maharashtra coast that could also be used to serve Goa and Karnataka. Some of the existing ports that have a deep draft and could be developed to become mega ports are: Mundra (Gujarat); Gangavaram (AP); Dhamra (Odisha); and Ennore (TN).

However, selection of sites for locating mega ports will require extensive modeling and analysis. First, all types of port traffic including containers and other commodities needs to be included in the analysis. Second, detailed data are required on the cost of development of candidate ports, and then detailed modeling is required to examine the costs and benefits of various alternative selections from a short list of potential sites.

Investments in the Port Sector

Indicative estimates of the required plan-wise investments in the ports sector for handling coal and POL are given in Table 7.6 which is repeated below.   We estimate that an investment of about Rs 140,000 crore will be required over the twenty year period.

Table 7.6 Investment Required in Ports for Coal and POL

	2011-12	2016-17	2021-22	2026-27	2031-32
Traffic (Mt)					
Thermal Coal	48	88	138	266	356
Coking Coal	30	65	108	173	238
POL	334	490	596	725	816
Capacity (Mt)					
Thermal Coal	62	114	179	346	463
Coking Coal	39	85	140	225	309
POL	434	637	775	943	1,061
Incremental Capacity Reqd (Mt)					
Thermal Coal		52	65	166	117
Coking Coal		46	56	85	85
POL		203	138	168	118
Cost of Creating Capacity (Rs crores)					
Thermal Coal		2,860	3,575	9,152	6,435
Coking Coal		2,503	3,075	4,648	4,648
POL		10,546	7,166	8,720	6,152
Total		15,908	13,815	22,520	17,234
Cost of Other Facilities		15,908	13,815	22,520	17,234
Total Investment required		31,816	27,630	45,040	34,468
Total Cumulative Investment 2012-2032 (Rs Crores)					1,38,954

Source: Ministry of Shipping (2012) and Working Group Research

Annex I. Order Setting Up Working Group on Bulk Transport

No. 3/1/2010-Tpt.
Government of India
Planning Commission
National Transport Development Policy Committee (NTDPC)

6th Floor, Capital Court,
Olof Palme Marg, Munirka,
New Delhi-110 067.
Dated: 5th April, 2011.

Subject: Working Group on Integrated Strategy for Bulk Transport of Energy and Related Commodities in India.

The surge in economic growth witnessed in recent years in India has strained the capacity of its transport system as well as energy supply, particularly electric power. The government's ambitious development targets and plans as well as popular discourse attest to importance of addressing such binding infrastructure constraints in a decisive manner over the next decade in order to sustain high levels of economic growth and to make it more inclusive.

Movement of bulk commodities is a major role of India's transportation system. For example, coal accounts for almost half the freight volume on Indian Railways which is a major supplier of transport services to the electric power and steel industries. Indeed, the congestion caused by inadequate expansion in transport capacity to date, especially on crucial links and corridors underlies many issues such as security of supply chains, inventory of raw materials, port-handling, etc. affecting industry.

The future poses more profound challenges. Even if ambitious aims to improve energy intensity of the Indian economy are achieved, sustaining economic growth at 8-10% *per annum* over the next two decades will require massive increases in power generation and transportation of bulk commodities such as coal, iron and steel. The Integrated Energy Policy foresees generation capacity increasing six-fold to 960 GW by 2031-32 and coal requirements expanding commensurately to 2-3 BT p.a. Out of this requirement, approximately 10 to 15% will be imported coal. The task ahead is also rendered more difficult by the evolving economic geography and structural changes in the energy system, such as the increasing role of natural gas and growing imports of coal that will impose major new demands on the transport networks. Current projections for coal imports in 2031-32 and LNG imports in 2029-30 for example, are 930 million tones and 162 MMSCMD respectively.

Finally, there is increasing recognition of the adverse environmental impacts, including not just local pollution and damage to habitats and/or livelihood of vulnerable groups but also global climate change that need to be addressed in an economically efficient, equitable and effective manner.

Development plans from the key ministries of the government as well as initiatives and investment proposals from the private sector seek to address the issues alluded to above. However, the needs are vast and multifaceted, while resources are necessarily limited and more importantly the issues are intimately interrelated and the viability of solutions is interdependent both in terms of the nature of the investment (e.g. transport coal or transmit power) as well as the timing and duration of execution. Hence a piecemeal approach to planning could be severely suboptimal leading to colossal wastage of resources and lost time.

Keeping in view what is stated above, it has been decided by the National Transport Development Policy Committee (NTDPC) to constitute a Working Group on Integrated Strategy for Bulk Transport of Energy and Related Commodities in India. The composition and Terms of Reference of the Working Group are as under:-

1. Composition

1.	Shri P. Uma Shankar, Secretary, Ministry of Power - Chairman
2	Shri B.N. Puri, Member-Secretary, NTDPC
3	Shri Pradeep Bhatnagar, Additional Member (Traffic), Railway Board
4	Representative* of Ministry of Coal
5	Representative* of Ministry of Shipping
6	Representative* of Ministry of Steel.
7	Representative* of Ministry of Petroleum & Natural Gas
8	Representative* of Ministry of Road, Transport & Highways
9	Representative* of Ministry of Environment and Forest
10	Representative of State Govt.
11	Representative of State Govt.
12	Representative of CEA
13	Private Sector Representative, Power
14	Private Sector Representative, Gas
15	Private Sector Representative, Steel
16	Dr. Anupam Khanna, Principal Adviser, NTDPC - Convenor
	* Not below the rank of Joint Secretary.

The Chairman of Working Group may co-opt/invite representative, special experts, functionaries including that of Central Public Sector.

2. **Terms of Reference**

1. Develop demand scenarios for electric power and natural gas and steel for final consumption at 5-year intervals (2017, 2022, 2027 and 2032) disaggregated into a suitable number of spatial locations (transmission nodes) and consumer type.

2. Identify production locations (existing and potential) for the following:
   a. Electric Power Generation, separating out current and potential hydro- and nuclear power plants.
   b. Iron & Steel plants
   c. Coal Mines (differentiated by type of coal and ash content)

3. Indicate current and potential port terminals for
   a. Coal
   b. LNG
   c. Landing site for offshore natural gas

4. Indicate current and potential transport links
   a. Railway corridors
   b. Road Corridors
   c. Inland Waterways

   d. Possible Coal Slurry pipelines
   e. Natural Gas pipelines
   f. Coastal Shipping options for coal

5. Study the economics of transmission of energy vs. transportation of fuel (coal, natural gas) within a coherent and analytically tractable framework.
6. Make recommendation for rationalization of coal linkage by optimizing the distance of coal transportation from source of coal supply to power station taking into account economic and environmentally significant variables such as calorific values, ash and sulfur content, carbon emissions, etc.
7. Estimate the rail, road and port capacities required and associated investment to meet the demand.
8. Develop estimates of both environmental externalities as well as economic cost of shortage of energy and transport services.
9. Examine laws, rules and regulations pertaining to transport in connection with the ToR above and suggest legal, organizational, institutional and procedural reforms needed to achieve the objectives of the integrated strategy.

3. The report of the Working Group should pay due regard to the uncertainties inherent in the development of such a complex system over a long period of twenty years. Thus it is necessary to distinguish what is clearly known now and what the Group believes needs to be known through suitable an analyses. The aim should be to set robust directions for the long-term that can be adapted as events unfold but also recommend immediate concrete actions that address critical bottlenecks and identify promising options (e.g. for new corridors, dedicated facilities) in order to begin planning investments in a timely manner.

4. The Group may get special studies carried out by experts.

5. The expenditure on studies commissioned by the Working Group would be borne by the Ministry of Power.

6. The Group may visit such places and consult such stakeholders, key users and experts as may be considered necessary for its work.

7. The Chairman may co-opt up to two additional members.

8. The Working Group shall submit its report in July, 2011.

9. The non-official members of the Working Group will be paid TA/DA in accordance with the guidelines of NTDPC. The official Members will be paid TA/DA as per their entitlement by concerned Ministry/Departments where they are working.

(B.N. Puri)
Member Secretary (NTDPC)

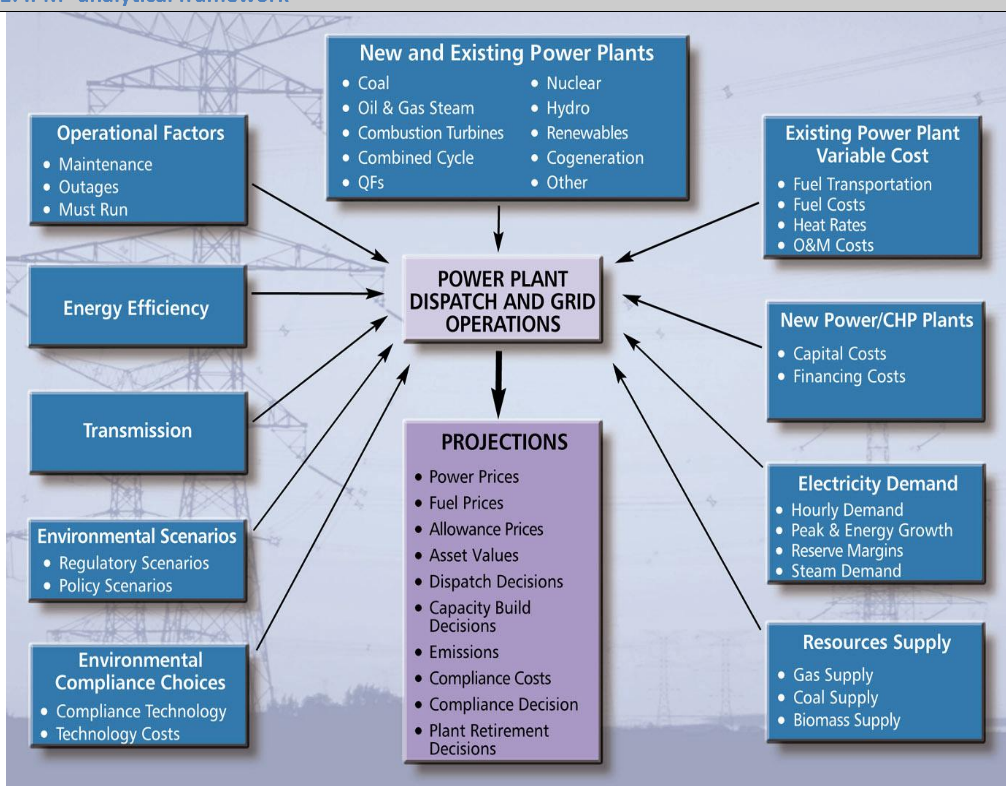
Copy to

1. Chairman, NTDPC
2. All the Members of the Working Group

Annex II. Overview of Integrated Planning Model® (IPM®)

The modelling of the power sector discussed in Chapter 4 was done using ICF International's principal modelling tool - the Integrated Planning Model® (IPM®). This uses a linear programming formulation to select investment options and to dispatch generating and load management resources to meet overall electric demand today and on an ongoing basis over the chosen planning horizon. System dispatch is optimised given the security requirements, resource mix, unit operating characteristics, fuel and other costs including environmental costs, and transmission possibilities. The model incorporates innovations in several areas of generation modelling such as representing inter-regional transmission, coal and gas flows, environmental constraints and ancillary service pricing algorithms in order to capture various real-world operating circumstances.Figure 1 illustrates the analytical framework used.

Figure 1: IPM® analytical framework



India-Integrated Planning Model® (I-IPM®)

IPM® has been specifically adapted to align with the India power market. Key adjustments include endogenous treatment of energy not served and forecasting of the willingness-to-pay-price for fuel shortages. The India IPM® is backed by an extensive database capturing all the parameters of the Indian power sector. The key assumptions include:

- On generation it includes data on all power plants, their costs, operation parameters and fuel capability. The database also includes all new power plants currently under construction, along with characteristics of new unplanned units
- Demand is represented at the state level along with demand profiles for each.
- Fuel supply is extensively treated with distinct supply regions and transport infrastructure and costs
- Transmission capability between states, including proposed new builds is also captured
- Assumptions on the air pollution regulation can also be simulated along with the compliance technology cost and performance

Outputs will include optimal generation capacity expansions including mothballing, retrofits, retirements and new builds, optimal transmission expansion builds, optimal fuel transportation and optimal compliance plans for individual generation units, allowance prices, compliance costs, renewable energy premia and electricity prices.

Purpose

As a forward-looking model, I-IPM® can easily tackle the complex task of determining the most efficient capacity adjustment path. Because the model solves for all years simultaneously, it will select the most appropriate solution to ensure that system security is not compromised (e.g. build new baseload or peaking units, retrofit or repower existing units), select units that should be retired or mothballed, and identify the timing of such events. By using this degree of foresight, the model replicates the approach used by power plant developers, regulatory personnel, and energy users when reviewing investment options.

The model replicates, as much as possible, the perspective of power plant developers, regulatory personnel, and the public, in reviewing important investment options for the electric power industry and electricity consumers. Decisions are made based on minimizing the net present value of capital plus operating costs over the full planning horizon.

Applications

Among the types of analyses that can be conducted with IPM® are:

Power price forecasts: IPM® can be used to predict wholesale power prices using scenarios developed through the IPM® database interface.

Strategic planning: IPM® can be used to assess the costs and risks associated with alternative utility and consumer resource planning strategies as characterized by the portfolio of options included in the input data base.

Policy analysis: IPM® is frequently used to determine the impacts of environmental and other regulatory policy proposals. With IPM®, the costs and benefits of alternate policy decisions can be readily recognized and accordingly planned for in any policy decisions. Examples of policy concerns that could be examined with IPM® include impact analysis of environmental policy options including costs to generators and consumers of electricity, cost-benefit analysis of national standards rulemaking such as proposals for regional transmission organization policy and design, local impacts of siting policy decisions on incumbent suppliers and consumers, and impacts of decisions regarding rules associated with trading across borders.

Environmental compliance planning: IPM® provides generators with the profit-maximizing solution to planning for specific or probable environmental control policies. IPM® simultaneously evaluates all potential control options based on expected performance and costs for individual assets or portfolios of assets to determine the optimal control options and timing decisions based on expected policy implementation.

Asset management: Various approaches can be evaluated for meeting environmental constraints (e.g., limits on hourly, daily, or annual emissions), fuel use constraints (e.g., optimum allocation of limited fuel supplies to alternative plants), load management constraints (e.g., dispatch of directly controlled loads given limits on the availability and scheduling of service interruptions), and other operational constraints (e.g., "must-run" considerations and "area-protection" concerns). The model also can address optimum usage of pumped storage facilities and economic and bulk power purchases from out-of-state utilities.

Detailed modeling of dispatch: IPM® dispatch algorithms are very accurate and have been benchmarked against detailed utility dispatch models. IPM® is regularly used to perform due diligence analysis on power plant forward performance and dispatch.

Analysis of uncertainty: The efficiency of the model's computational algorithms allows it to be used with various techniques for analyzing the potential impacts of uncertain future conditions (e.g., load growth, fuel availability and prices, environmental regulations, costs and performance of resource options) and the risks associated with alternative planning strategies. Alternative approaches that have been used for analyzing uncertainty with IPM® include sensitivity analysis, decision analysis, and modeling uncertainty endogenously by incorporating specific factors that are uncertain and the associated probabilities for different values or expectations for these factors directly into the linear programming structure.

SCENARIO ANALYSIS

The scenarios help to capture the impact of regulatory and structural uncertainty. By comparing the volumes/price curves in the alternate scenarios against the volumes/price curves of the baseline scenario it is possible to estimate regulatory and structural risks on volumes/prices and valuation. Some examples of alternate scenarios could be:

1. **Demand uncertainty:** Represent a low demand scenario in the short to medium term to reflect the load shedding by distribution utilities.
2. **Generation capacity addition uncertainty:** Represent a high generation capacity addition scenario to simulate a situation where capacity addition initiatives materialize as planned.
3. **Limited Transmission Expansion:** Represent a low case transmission addition scenario to simulate failure to achieve planned growth in the near term and less than optimal growth in the longer term. This scenario can help capture resultant impact on interstate sales.
4. **Coal market uncertainty:** Represent a high case domestic coal production scenario to simulate restructuring and efficiency improvement of the coal sector. Possibility of broader marketing from captive coal block could also be introduced.
5. **New transmission pricing regime:** Represent the new transmission pricing regime with the advent of zonal marginal prices vis-à-vis current postage stamp methodology.
6. **Renewable capacity additions:** Represent a scenario where focus is on renewable capacity addition and mandatory renewable generation purchase targets are set for every state. Different RPO levels – 10, 15, 20, 25 percent by 2025 can be modeled
7. **Emissions cost uncertainty:** Represent a scenario where CO2 emissions costs need tobe internalized. An assumed cost of $7-10/tonne could be used to reflect current sentiments on carbon prices.

Options assessment: IPM® can be used to "screen" alternative resource options and option combinations based upon their relative costs and potential earnings.

Technology penetration analysis: IPM® simultaneously considers options for generation expansion based on locational megawatt requirements. By evaluating current investment and expected future investment options, IPM® determines the ideal timing for investment decisions of alternate capacity types. The decision to invest in alternate technologies is generally based on the least cost option for the system while considering specific investment incentives such as tax credits for wind generators or funding programs for clean coal options.

Estimation of avoided costs: Shadow prices[10] from the linear programming solution can be used to determine avoided costs by season or time-of-day for pricing purchases from qualifying facilities, independent power producers, or economy and/or firm power purchases from other utilities. Shadow prices also can be used to assess the economic value of relaxing a constraint (e.g., What is the marginal cost of emissions reductions for the utility?), to conduct marginal cost studies, and to determine the cost reductions of alternative options in order for these options to be competitive with those options selected by the model or the "preferred" options. This greatly enhances the capability to use the model and its outputs as a screening tool.

Integrated resource planning: IPM® can be used to perform least-cost planning studies that simultaneously optimize demand-side options (load management and conservation), non-utility supply, renewable options and traditional utility supply-side options.

[10] Shadow prices provide a measure of the value of incremental capacity and energy or the value of relaxing system operations constraints. Since these costs are not explicitly incurred by utilities or consumers but reflect a willingness to pay for changing binding limitations on their actions or decisions.

Annex III. Additional Data and Calculations

Grades of Coal Used in India

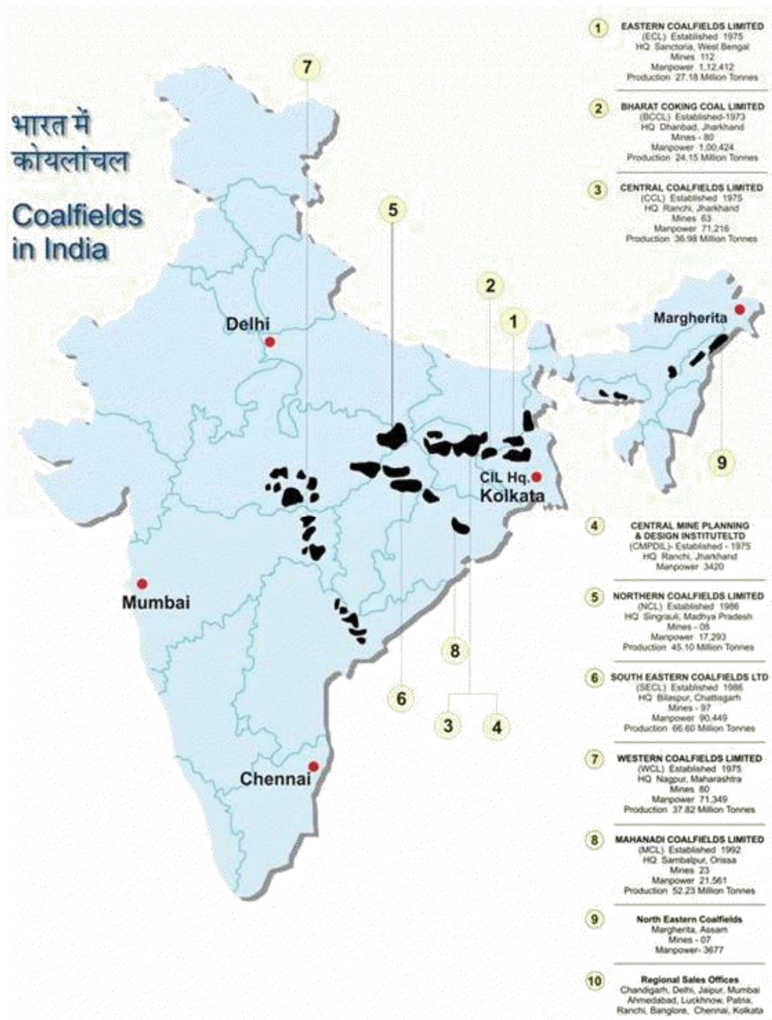
Grade of Coal	Gross Calorific Value (kcal/kg)
A	> 6,401
B	5,801-6,400
C	5,401-5,800
D	4,801-5,400
E	4,201-4,800
F	3,601-4,200
G	3,201-3,600

Source: Report of Sub Group 2

Annex III. 2.2

Subsidiaries of Coal India Limited and their Location

- Bharat Coking Coal Limited (BCCL)
- Eastern Coalfields Limited (ECL)
- Central Coalfields Limited (CCL)
- Northern Coalfields Limited (NCL)
- Western Coalfields Limited (WCL)
- South -Eastern Coalfields Limited (SECL)
- Mahanadi Coalfields Limited (MCL)
- Central Mine Planning & Design Institute Limited (CMPDI)


भारत में
कोयलांचल
Coalfields
in India
Delhi
Margherita
CIL Hq.
Kolkata
Mumbai
Chennai
1 EASTERN COALFIELDS LIMITED
(ECL) Established 1975
HQ Sanctoria, West Bengal
Mines 112
Manpower 1,12,412
Production 27.18 Million Tonnes
2 BHARAT COKING COAL LIMITED
(BCCL) Established-1973
HQ Dhanbad, Jharkhand
Mines - 80
Manpower 1,00,424
Production 24.15 Million Tonnes
3 CENTRAL COALFIELDS LIMITED
(CCL) Established 1975
HQ Ranchi, Jharkhand
Mines 63
Manpower 71,216
Production 36.98 Million Tonnes
4 CENTRAL MINE PLANNING
& DESIGN INSTITUTELTD
(CMPDIL)- Established - 1975
HQ Ranchi, Jharkhand
Manpower 3420
5 NORTHERN COALFIELDS LIMITED
(NCL) Established 1986
HQ Singrauli, Madhya Pradesh
Mines - 08
Manpower 17,293
Production 45.10 Million Tonnes
6 SOUTH EASTERN COALFIELDS LTD
(SECL) Established 1986
HQ Bilaspur, Chattisgarh
Mines - 97
Manpower 90,449
Production 66.60 Million Tonnes
7 WESTERN COALFIELDS LIMITED
(WCL) Established 1975
HQ Nagpur, Maharashtra
Mines 80
Manpower 71,349
Production 37.82 Million Tonnes
8 MAHANADI COALFIELDS LIMITED
(MCL) Established 1992
HQ Sambalpur, Orissa
Mines 23
Manpower 21,561
Production 52.23 Million Tonnes
9 North Eastern Coalfields
Margherita, Assam
Mines - 07
Manpower- 3677
10 Regional Sales Offices
Chandigarh, Delhi, Jaipur, Mumbai
Ahmedabad, Lucknow, Patna,
Ranchi, Banglore, Chennai, Kolkata

Annex III.2.3 State-Wise Reserves of Coal

(A) : GONDWANA COALFIELDS :-

State	Gross Geological Resources of Coal (MT)			
	Proved	Indicated	Inferred	Total
Andhra Pradesh	9296.85	9728.37	3029.36	22054.58
Assam	0	2.79	0	2.79
Bihar	0	0	160	160
Chhattisgarh	12878.99	32390.38	4010.88	49280.25
Jharkhand	39760.73	32591.56	6583.69	78935.98
Madhya Pradesh	8871.31	12191.72	2062.70	23125.73
Maharashtra	5489.61	3094.29	1949.51	10533.41
Orissa	24491.71	33986.96	10680.21	69158.88
Sikkim	0	58.25	42.98	101.23
Uttar Pradesh	866.05	195.75	0	1061.80
West Bengal	11752.54	13131.69	5070.69	29954.92
Total	113407.79	137371.76	33590.02	284369.57

(B) : TERTIARY COALFIELDS:

State	Geological Resources of Coal(MT)			
	Proved	Indicated	Inferred	Total
Arunachal Pradesh	31.23	40.11	18.89	90.23
Assam	464.78	42.72	3.02	510.52
Meghalaya	89.04	16.51	470.93	576.48
Nagaland	8.76	0	306.65	315.41
Total	593.81	99.34	799.49	1492.64

Source: Report of Sub-Group 2

Annex III. 2.4

Refineries in India

	Company	Location of Refinery	Capacity (Mtpa)
1.	Indian Oil Corporation Limited (IOCL)	Guwahati, Assam	1.00
2.	Indian Oil Corporation Limited (IOCL)	Barauni, Bihar	6.00
3.	Indian Oil Corporation Limited (IOCL)	Koyali, Vadodra, Gujarat	13.70
4.	Indian Oil Corporation Limited (IOCL)	Haldia, West Bengal	7.50
5.	Indian Oil Corporation Limited (IOCL)	Mathura, Uttar Pradesh	8.00
6.	Indian Oil Corporation Limited (IOCL)	Digboi, Assam	0.65
7.	Indian Oil Corporation Limited (IOCL)	Panipat, Haryana	15.00
8.	Indian Oil Corporation Limited (IOCL)	Bongaigaon, Assam	2.35
9.	Hindustan Petroleum Corporation Limited (HPCL)	Mumbai, Maharashtra	6.50
10.	Hindustan Petroleum Corporation Limited (HPCL), Visakh	Vishakapatnam, Andhra Pradesh	8.30
11.	Bharat Petroleum Corporation Limited (BPCL)	Mumbai, Maharashtra	12.00
12.	Bharat Petroleum Corporation Limited (BPCL)	Kochi, Kerala	9.50
13.	Chennai Petroleum Corporation Limited (CPCL)	Manali, Tamil Nadu	10.50
14.	Chennai Petroleum Corporation Limited (CPCL)	Nagapattnam, Tamil Nadu	1.00
15.	Numaligarh Refinery Ltd. (NRL)	Numaligarh, Assam	3.00
16.	Mangalore Refinery & Petrochemicals Ltd. (MRPL)	Mangalore, Karnataka	11.82
17.	Tatipaka Refinery (ONGC)	Tatipaka, Andhra Pradesh	0.066
18.	Bharat Petroleum Corporation Limited & Oman Oil Company, joint venture, Bina	Bina, Madhya Pradesh	6.00
19.	Reliance Industries Limited (RIL); Private Sector	Jamnagar, Gujarat	33.00
20.	Reliance Petroleum Limited (SEZ); Private Sector	Jamnagar, Gujarat	27.00
21.	Essar Oil Limited (EOL); Private Sector	Jamnagar, Gujarat	10.50
	Total		**193.386**

Source: MoP&NG website

Annex III. 2.5

State-wise Installed Capacity (Location-Wise) at the End of 11th Plan

SUMMARY OF STATEWISE INSTALLED CAPACITY (LOCATION-WISE) AT THE END OF 11TH PLAN

Sl. No.	STATE/ UTs	Thermal	Hydro	Nuclear	Total
1	DELHI	2298.4	0		2298.4
2	HARYANA	5255.51	0		5255.51
3	HIMACHAL PRADESH	0.13	7293		7293.13
4	JAMMU & KASHMIR	183.94	2340		2523.94
5	PUNJAB	2630	1206.3		3836.3
6	RAJASTHAN	5143.13	411	1180	6734.13
7	UTTAR PRADESH	15920.14	501.6	440	16861.74
8	UTTARAKHAND	0	3426.35		3426.35
9	CHANDIGARH	0	0		0
SUB TOTAL NORTHERN REGION		**31431.25**	**15178.25**	**1620**	**48229.5**
10	CHHATTISGARH	9033	120		9153
11	GUJARAT	16042.29	1990	440	18472.29
12	MAHARASHTRA	15608	2887	1400	19895
13	MADHYA PRADESH	6192.5	2395		8587.5
14	GOA	48	0		48
15	DAMAN & DIU	0	0		0
16	DADRA & NAGAR HAVELI	0	0		0
SUB TOTAL WESTERN REGION		**46923.79**	**7392**	**1840**	**56155.79**
17	ANDHRA PRADESH	12977.7	3783.35		16761.05
18	KARNATAKA	5014.42	3585.4	880	9479.82
19	KERALA	790.02	1881.5		2671.52

20	TAMIL NADU	7897.96	2122.2	440	10460.16
21	PUDUCHERRY	32.5	0		32.5
SUB TOTAL SOUTHERN REGION		**26712.6**	**11372.45**	**1320**	**39405.05**
22	BIHAR	2770	143.2		2913.2
23	JHARKHAND	4710	130		4840
24	ORISSA	5690	2027.5		7717.5
25	SIKKIM	5	570		575
26	WEST BENGAL	12263.57	977		13240.57
SUB TOTAL EASTERN REGION		**25438.57**	**3847.7**	**0**	**29286.27**
27	ARUNACHAL PRADESH	15.88	405		420.88
28	ASSAM	672.39	300		972.39
29	MANIPUR	45.41	105		150.41
30	MIZORAM	51.86	0		51.86
31	MEGHALYA	2.05	315		317.05
32	NAGALAND	2	75		77
33	TRIPURA	237.35	0		237.35
SUB TOTAL N.EASTERN REGION		**1026.94**	**1200**	**0**	**2226.94**
34	ANDMAN & NICOBAR ISLANDS	60.05	0		60.05
35	LAKSHDWEEP	9.97	0		9.97
SUB TOTAL ISLAND		70.02	0	0	70.02
	TOTAL	**131603.2**	**38990.4**	**4780**	**175373.6**

Note: 1. Thermal capacity includes 18318.05 MW Gas and 1199.75 MW Diesel based power projects.

2. Excludes likely Installed Capacity of about 24,500 MW from Renewables estimated by end of 11th Plan.

Source: Report of Sub Group 2

Annex III.2.6

State-Wise Potential Capacity Additions

S. No	Region	12th Plan		13th Plan		14th Plan		15th Plan	
	State	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)
1	**NR**								
1.1	J&K	02	780	01	1000	07	3963	01	280
1.2	Punjab	02	1590	05	2611	04	5120	01	700
1.3	Rajasthan	04	3260	1	1400	04	5280	01	1400
1.4	Chandigarh	0	0	0	0	0	0	00	0
1.5	Haryana	0	660	01	1400	1	1400	01	660
1.6	Uttarakhand	0	1025	05	1971	14	4072	06	979
1.7	Uttar Pradesh	0	3920	05	6600	6	4205	05	4710
1.8	HP	11	2762	02	306	07	1906	10	1919
1.9	**TOTAL**	**28**	**13997**	**20**	**15288**	**43**	**25946**	**25**	**10648**
2	**ER**								
2.1	Bihar	03	4690	02	2480	01	125	06	8920
2.2	Jharkhand	03	1580	04	7020	03	2042	00	0
2.3	West Bengal	01	250	04	3320	05	3984	06	7336
2.4	Orissa	06	4600	03	2760	09	13450	07	7350
2.5	Sikkim	05	1367	07	1274	02	576	05	450
2.6	**TOTAL(ER)**	**18**	**12487**	**20**	**16854**	**20**	**20177**	**24**	**24056**
3	**WR**								

S. No	Region	12th Plan		13th Plan		14th Plan		15th Plan	
	State	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)
3.1	M.P	08	8650	06	6700	11	14512	08	9380
3.2	Maharashtra	13	13770	07	7890	6	9260	03	4890
3.3	Chhattisgarh	10	8895	13	12380	06	8130	19	20940
3.4	Gujarat	04	6420	05	5780	03	7480	03	6040
3.5	**TOTAL (WR)**	**35**	**37735**	**31**	**32750**	**26**	**39382**	**33**	**41250**
4	**SR**								
4.1	A.P	07	4780	07	11840	13	17042	06	15200
4.2	Tamil Nadu	03	2700	05	6480	05	4120	06	9860
4.3	Kerala	02	100	03	110	01	163	02	130
4.4	Karnataka	00	0	03	3100	05	5640	03	1865
4.5	**TOTAL (SR)**	**12**	**7580**	**18**	**21530**	**24**	**26965**	**17**	**27055**
5	**NER**								
5.1	Ar. Pradesh	03	2710	07	6870	12	8231	51	21854
5.2	Assam	02	350	0	0	03	460	03	150
5.3	Meghalaya	01	40	0	0	0	0	12	2265
5.4	Mizoram	01	60	01	460	0	0	0	0
5.5	Nagaland	00	0	0	0	0	0	1	140
5.6	Tripura	02	826	0	0	0	0	0	0
5.7	Manipur	00	0	0	0	02	1566	4	246
5.8	TOTAL (NER)	09	3986	08	7330	17	10257	71	24655

S. No	Region	12th Plan		13th Plan		14th Plan		15th Plan	
	State	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)	Project locations (Nos.)	Capacity (MW)
	Total (All India)	**102**	**75785**	**97**	**93752**	**130**	**122727**	**170**	**127664**
	Nuclear Projects of BHAVINI				1000		500		4000
	Grand Total	**102**	**75785**	**97**	**94752**	**130**	**123227**	**170**	**131664**

PROJECTION OF STEEL CAPACITY IN MAJOR STEEL PRODUCING STATES

(CRUDE STEEL CAPACITY IN MILLION TONNES)

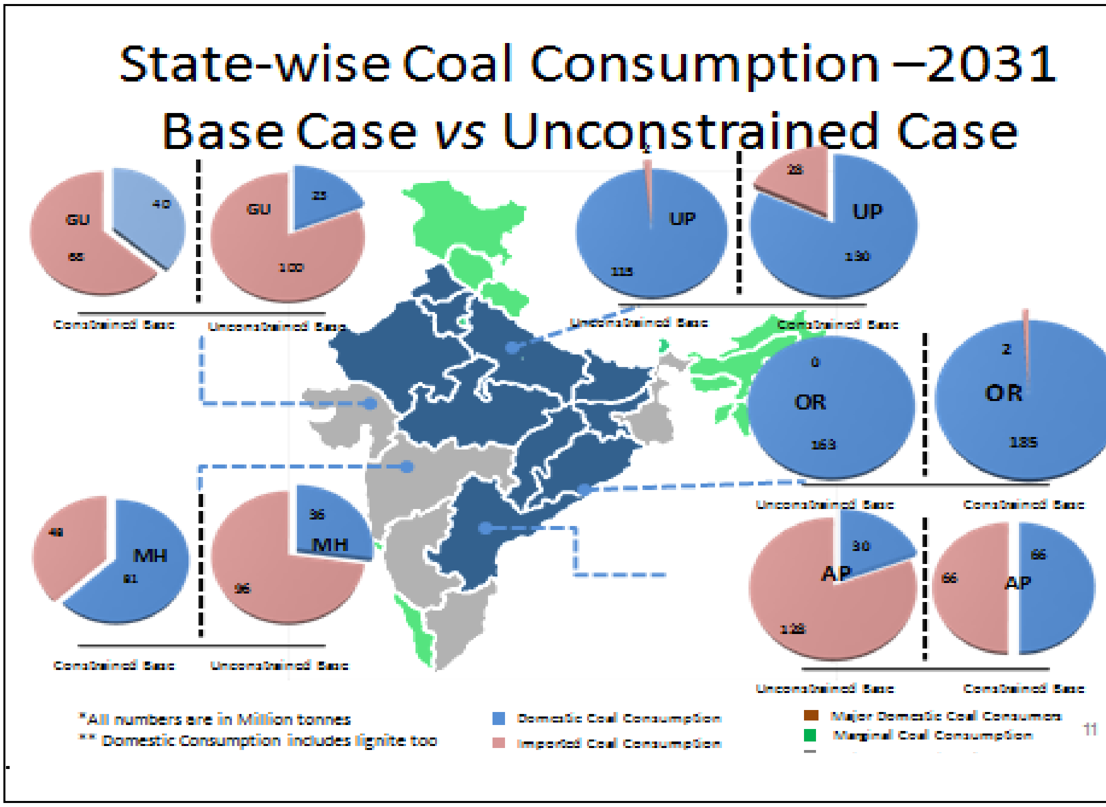
		2016-17			2021-22			2026-27			2031-32		
Location/ State		Large	Small/ Medium	**Total**	Large	Small/ Medium	**Total**	Large	Small/ Medium	**Total**	Large	Small/ Medium	**Total**
Orissa	OR	25.99	4.84	**30.83**	45.17	8.41	**53.58**	72.80	13.56	**86.36**	107.86	20.09	**127.95**
Chhattisgarh	CH	12.71	3.84	**16.54**	22.08	6.67	**28.75**	35.60	10.74	**46.34**	52.74	15.92	**68.66**
Jharkhand	JH	16.65	1.29	**17.94**	28.94	2.25	**31.19**	46.64	3.63	**50.27**	69.11	5.37	**74.48**
West Bengal	WB	4.04	4.62	**8.67**	7.03	8.03	**15.06**	11.33	12.95	**24.28**	16.79	19.18	**35.97**
Karnataka	KT	10.59	0.72	**11.32**	18.41	1.26	**19.67**	29.67	2.03	**31.70**	43.96	3.01	**46.97**
Tamil Nadu	TN	1.66	2.40	**4.05**	2.88	4.16	**7.04**	4.64	6.71	**11.35**	6.87	9.95	**16.82**
Maharashtra	MH	4.18	2.75	**6.93**	7.27	4.78	**12.05**	11.71	7.71	**19.42**	17.35	11.42	**28.77**
Andhra Pradesh	AP	5.74	2.23	**7.97**	9.97	3.87	**13.85**	16.08	6.25	**22.32**	23.82	9.25	**33.07**
Gujarat	GUJ	8.20	1.37	**9.57**	14.25	2.38	**16.63**	22.97	3.84	**26.81**	34.03	5.69	**39.71**
Other Locations	OTHER	6.09	6.09	**12.19**	10.59	10.59	**21.18**	17.07	17.07	**34.14**	25.29	25.29	**50.59**
Total		95.84	30.16	**126.00**	166.59	52.41	**219.00**	268.52	84.48	**353.00**	397.83	125.17	**523.00**

Source: MoS (2012a)

Statewise Net Energy for Load (GWh)															
	Base Case					**Low Case**					**High Case**				
States	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**
AP	102,250	156,173	219,927	305,761	405,569	99,195	138,398	181,981	234,000	297,795	110,232	150,205	217,000	290,713	391,686
AR	451	552	721	1,083	1,450	438	489	596	829	1,065	508	689	1,020	1,582	2,396
AS	8,457	11,099	15,861	22,163	29,324	8,204	9,836	13,125	16,961	21,532	8,187	13,315	23,318	33,761	48,404
BI	16,626	29,873	46,831	72,943	98,066	16,129	26,473	38,751	55,824	72,006	17,165	33,589	71,655	110,365	166,251
CH	36,422	48,011	67,316	93,755	124,586	35,334	42,547	55,702	71,751	91,480	36,566	48,805	69,031	92,256	124,057
DL	28,818	37,361	52,698	72,536	94,353	27,957	33,109	43,606	55,512	69,280	29,700	40,102	57,968	81,512	114,162
GO	3,873	5,166	7,269	10,059	13,279	3,757	4,578	6,015	7,698	9,750	3,908	5,318	7,383	8,155	9,415
GU	107,141	141,947	203,642	285,612	379,587	103,940	125,791	168,507	218,580	278,718	108,447	145,392	203,245	250,500	315,724
HP	8,433	10,663	14,225	18,701	24,000	8,181	9,449	11,770	14,312	17,623	8,509	10,984	15,090	20,608	28,197
HY	39,983	56,969	87,376	128,737	171,485	38,788	50,485	72,300	98,523	125,916	41,032	57,372	84,045	106,098	136,312
JH	26,370	34,904	48,127	66,498	87,660	25,582	30,932	39,824	50,891	64,366	27,590	40,252	62,946	89,057	125,343
JK	20,586	23,340	24,410	31,476	38,759	19,971	20,683	20,198	24,089	28,460	19,619	23,561	29,789	38,527	50,466
KE	20,723	26,435	35,035	45,923	59,133	20,103	23,426	28,991	35,145	43,419	22,010	31,424	47,808	65,708	90,362
KT	63,318	85,110	117,727	159,554	206,278	61,426	75,423	97,415	122,107	151,464	62,290	83,567	120,210	170,372	240,124
MG	2,020	2,412	3,277	4,517	5,888	1,960	2,137	2,712	3,457	4,324	1,859	2,743	4,344	6,197	8,781
MH	138,528	185,459	250,727	337,508	439,429	127,388	156,265	197,414	245,967	307,387	138,709	184,978	264,060	370,972	519,203
MN	612	948	1,687	2,725	3,682	594	840	1,396	2,086	2,704	703	1,248	2,433	3,885	6,024
MP	57,776	83,716	116,352	164,577	216,455	56,049	74,188	96,277	125,951	158,936	59,806	91,970	151,830	216,476	306,563
MZ	520	936	1,388	2,048	2,728	505	829	1,148	1,567	2,003	490	923	1,872	2,725	3,923
NG	663	834	1,163	1,741	2,318	643	739	962	1,332	1,702	704	1,044	1,688	2,587	3,881
OR	42,787	51,282	66,486	88,061	114,347	41,509	45,445	55,015	67,394	83,961	38,365	55,550	85,614	116,975	160,104
PB	55,969	76,679	96,396	120,414	148,509	52,507	65,949	77,336	89,216	105,422	54,989	72,679	99,935	121,818	152,259
RJ	64,747	87,085	118,800	163,348	212,575	62,813	77,174	98,303	125,011	156,087	65,941	96,820	152,039	212,742	296,785
SI	414	515	628	875	1,221	398	468	534	666	824	464	619	882	1,231	1,715
TN	96,810	125,078	175,559	240,551	315,856	90,784	107,341	141,142	180,005	227,199	97,750	128,357	177,996	233,879	310,342
TR	1,001	1,291	1,735	2,376	3,103	972	1,144	1,436	1,818	2,278	1,036	1,559	2,520	3,607	5,124
UP	95,055	144,135	214,934	311,498	415,103	92,215	127,730	177,850	238,390	304,796	99,777	166,256	299,162	439,363	637,128
UT	10,994	13,472	17,840	23,946	31,346	10,666	11,938	14,762	18,326	23,016	10,748	13,936	19,402	27,694	39,255
WB	53,721	74,420	110,145	158,580	211,218	51,718	65,482	90,608	120,695	154,267	56,405	87,790	147,329	214,710	309,438
Total	**1,105,068**	**1,515,865**	**2,118,282**	**2,937,566**	**3,857,307**	**1,059,726**	**1,329,288**	**1,735,676**	**2,228,103**	**2,807,780**	**1,123,509**	**1,591,047**	**2,421,614**	**3,334,075**	**4,603,424**

Source: Working Group Research (Model Output)

Annex III. 4.1



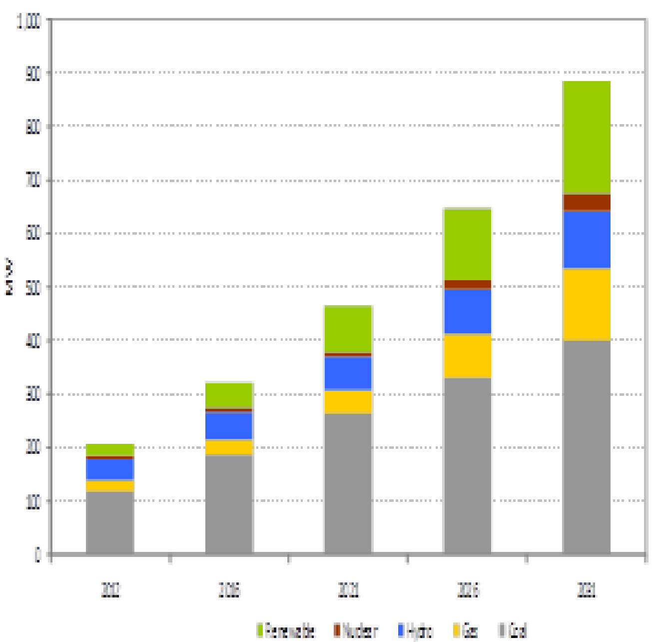
Source: Working Group Research (Model Outputs)

Capacity and Generation Mix Under Three Scenarios

1. Base Case

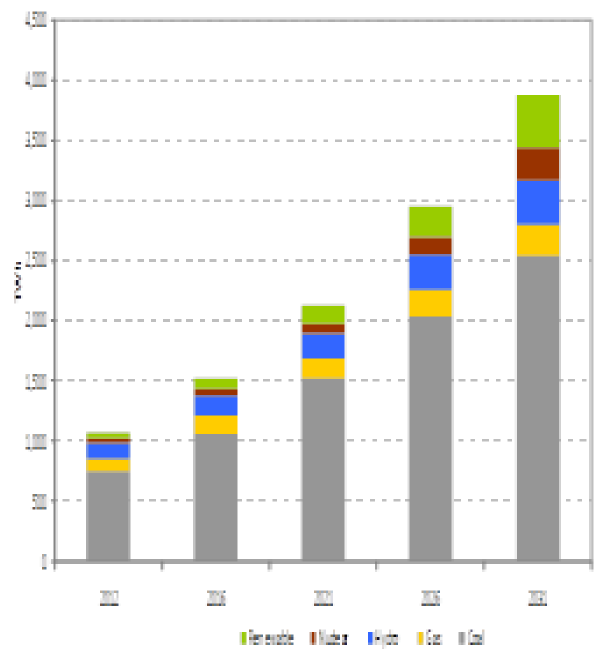
Capacity

- Coal is expected to dominate the capacity mix contributing ~45%, though the share decreases from the current share of 55%
- Renewable share expected to increase from current ~11% to ~24% by 2031
- Gas capacity share expected to increase from ~10% to ~15% by 2031 due to increasing peaking capacity requirement to support additional renewables
- Hydro share expected to decline to ~12%
- Nuclear share expected to increase marginally



Generation (Energy) Mix

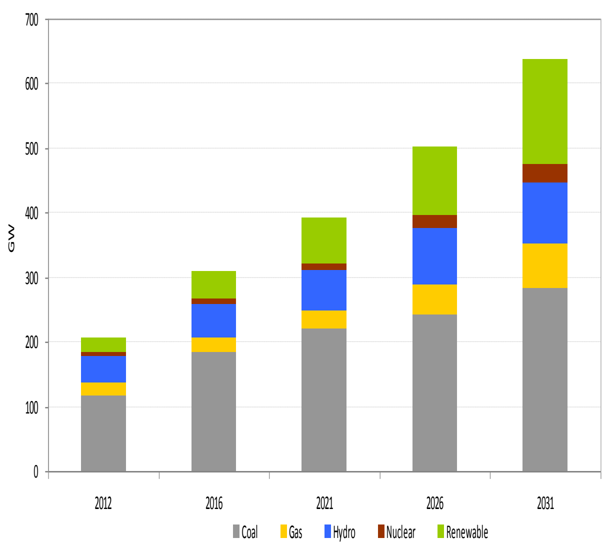
- Coal to dominate generation mix contributing ~65%, though the share decreases from the current share of 68%
- Gas share declining to 7% due to shift from current base load to mid-merit peaking position
- RPO increase the share of renewable from current 4% to 11% by 2031
- Nuclear share in generation mix to increase from current ~3% to 7% by 2031



Source: Working Group Research (Model Outputs)

<table>
<tr><th colspan="2">2. Low Case</th></tr>
<tr><th>Capacity</th><th>Generation (Energy) Mix</th></tr>
<tr><td>

- Coal is expected to dominate the capacity mix contributing ~45%, though the share decreases from the current share of 55%
- Renewable share expected to increase from current ~11% to ~25% by 2031
- Nuclear share expected to increase marginally to reach 5% and gas likely to maintain share of ~11%
- Hydro share expected to decline to ~15%



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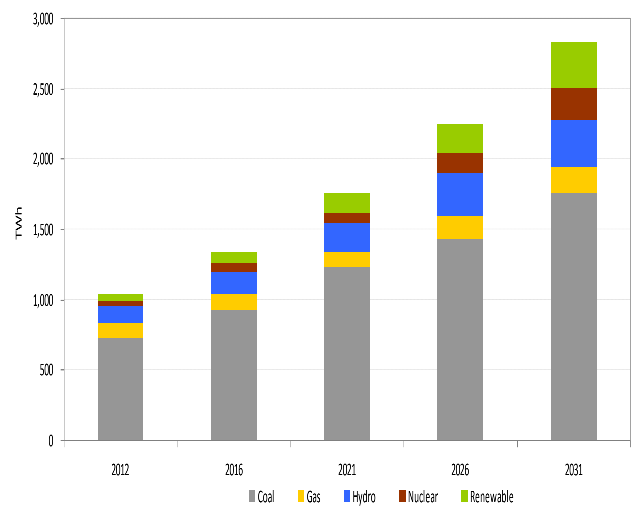
- Coal is expected to dominate the generation mix contributing ~62%, though the share decreases from the current %age share of 68%
- RPO increase the share of renewable from current 4% to 11% by 2031
- Nuclear share in the generation mix expected to increase from the current ~3% to 8% by 2031
- Gas share in mix declining due to shift from current base load to mid-merit peaking position



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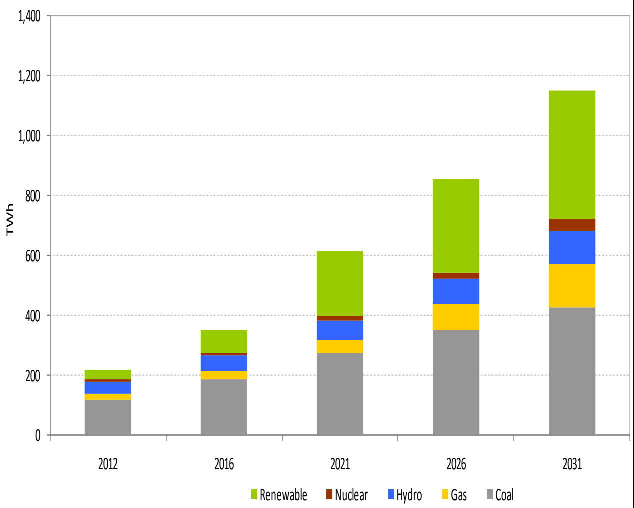
Source: Working Group Research (Model Outputs)

3. High Case

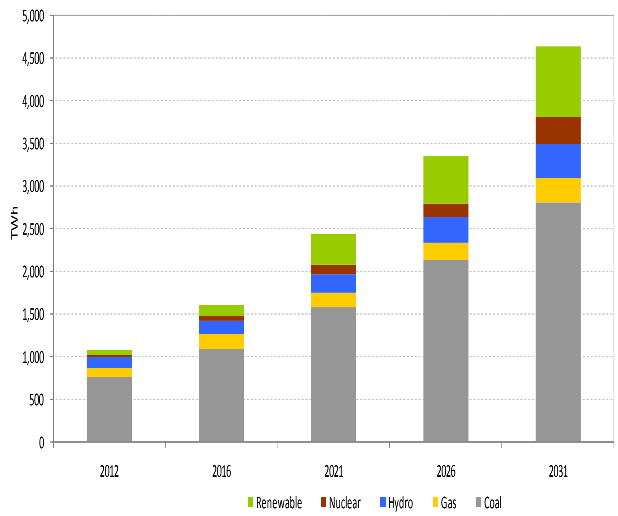
Capacity

- Coal is expected to dominate the capacity mix contributing ~37%, though the share decreases from the current percentage share of 55%
- Renewable share expected to increase from current ~11% to ~37% by 2031
- Gas and Nuclear share expected to increase marginally
- Hydro share expected to decline to ~10%



Generation (Energy) Mix

- Coal is expected to dominate the generation mix contributing ~60%, though the share decreases from the current share of 68%
- RPO increase the share of renewable from current 4% to 18% by 2031
- Nuclear share in the generation mix expected to increase from the current ~3% to 7% by 2031
- Gas share in mix declining due to shift from current base load to mid-merit peaking position



Source: Working Group Research (Model Output)

Annex III. 4.3

State-Wide Consumption of Domestic Coal (Mt)															
	Base Case					Low Case					High Case				
States	2011-12	2016-17	2021-22	2026-27	2031-32	2011-12	2016-17	2021-22	2026-27	2031-32	2011-12	2016-17	2021-22	2026-27	2031-32
AP	42	51	55	62	66	43	54	68	67	67	42	50	54	59	64
AR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BI	11	18	41	61	65	13	18	33	34	34	11	21	61	72	70
CH	44	70	104	114	134	47	75	106	110	119	42	67	105	117	131
DL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GU	26	21	27	32	40	20	21	28	34	41	25	21	27	31	40
HP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HY	21	21	17	11	11	17	21	25	30	28	21	21	13	11	11
JH	11	20	52	65	76	14	19	40	50	73	12	21	71	83	97
JK	4	4	0	0	0	4	1	1	1	0	4	4	0	0	0
KE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KT	11	10	7	7	7	11	8	8	9	7	10	10	7	7	7
MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MH	42	51	58	77	81	44	54	67	80	88	42	53	61	66	65
MN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MP	29	64	79	105	131	30	66	83	92	121	29	62	84	122	149
MZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OR	30	52	104	148	185	32	52	75	118	151	29	56	103	163	189
PB	14	23	21	18	21	13	20	24	29	31	14	23	20	18	22
RJ	19	26	23	28	52	18	22	27	27	52	20	26	20	28	51
SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TN	28	56	65	66	63	31	57	65	72	69	28	50	61	53	54
TR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UP	60	76	116	102	130	60	77	105	120	133	62	78	110	90	131
UT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WB	50	52	58	54	49	48	51	63	70	74	50	51	32	30	28
Total	**442**	**614**	**828**	**951**	**1,112**	**442**	**614**	**818**	**942**	**1,090**	**442**	**614**	**828**	**951**	**1,111**

Source: Working Group Research (Model Outputs)

Annex III. 4.4

Statewise Fuel Consumption of Imported Coal (MTs)															
	Base Case					Low Case					High Case				
States	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**
AP	4	11	27	49	66	4	5	5	5	7	4	12	28	54	91
AR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BI	1	3	1	1	1	0	0	0	1	1	1	3	1	9	15
CH	2	7	0	0	0	0	0	0	0	0	3	11	0	0	0
DL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GU	18	22	43	59	68	18	16	14	16	23	19	31	47	60	90
HP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HY	4	2	6	13	17	4	0	0	0	5	4	2	9	12	18
JH	2	0	0	0	0	0	0	0	0	0	2	0	0	0	1
JK	1	1	0	1	0	1	0	0	0	0	1	1	1	0	1
KE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KT	7	7	6	6	15	7	3	2	2	4	7	7	5	5	6
MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MH	14	20	17	35	48	12	2	3	3	4	14	20	17	43	86
MN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MP	1	2	1	1	1	0	0	0	0	0	1	2	1	1	1
MZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OR	3	2	0	2	2	2	0	0	0	0	3	2	0	2	2
PB	0	2	2	7	9	0	0	0	0	3	0	2	3	7	8
RJ	2	4	6	15	5	2	1	1	1	2	2	4	6	6	6
SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TN	4	5	24	37	47	4	0	1	1	4	4	8	15	35	42
TR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UP	4	0	4	28	28	2	0	0	0	8	4	0	7	32	28
UT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WB	6	1	1	14	48	**6**	**0**	**0**	**0**	**0**	6	2	18	29	67
India	**73**	**88**	**138**	**266**	**355**	**61**	**28**	**27**	**28**	**61**	**76**	**106**	**158**	**295**	**460**

Source: Working Group Research (Model Outputs)

Annex III. 4.5

Statewise Fuel Consumption of Gas (MMSCMD)															
	Base Case					Low Case					High Case				
States	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**
AP	7	19	9	6	1	7	15	1	1	0	7	19	7	3	0
AR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AS	4	4	6	7	6	4	4	4	5	7	4	4	6	6	5
BI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DL	3	8	4	8	14	4	8	5	4	1	3	8	7	4	9
GO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GU	19	18	21	22	19	18	12	16	17	17	19	18	19	18	18
HP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HY	2	2	2	2	9	2	2	2	1	0	2	2	2	2	2
JH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KT	0	0	7	13	17	0	0	0	11	15	0	0	6	9	14
MG	0	0	1	1	1	0	0	0	1	1	0	0	1	1	1
MH	9	16	16	25	28	9	4	15	25	27	9	16	16	25	28
MN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MP	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1
MZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
OR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RJ	4	4	3	2	1	4	3	2	2	0	4	4	3	2	2
SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TN	2	8	10	21	28	2	4	9	21	28	2	7	10	21	28
TR	1	3	1	0	0	1	3	3	2	0	1	3	1	1	1
UP	6	7	5	2	1	7	6	1	0	0	6	7	6	11	26
UT	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**0**	**0**	**0**
WB	0	0	2	5	5	0	0	0	0	0	0	1	5	5	7
Total	**58**	**90**	**88**	**116**	**129**	**58**	**63**	**58**	**90**	**97**	**58**	**91**	**90**	**109**	**142**

Source: Working Group Research (Model Outputs)

Annex III.4.6

Conventional Generation Capacity (MW)																									
	COAL					GAS					NUCLEAR					HYDRO					TOTAL (Coal, Gas, Hydro, Nuclear)				
State	2011-12	2016-17	2021-22	2026-27	2031-32	2011-12	2016-17	2021-22	2026-27	2031-32	2011-12	2016-17	2021-22	2026-27	2031-32	2011-12	2016-17	2021-22	2026-27	2031-32	2011-12	2016-17	2021-22	2026-27	2031-32
AP	8,909	13,490	22,051	30,600	38,189	3,536	5,501	6,113	11,458	14,800	299	299	299	299	299	3,652	4,032	4,032	4,032	4,032	16,396	23,322	32,495	46,389	57,320
AR	0	48	48	48	48	22	22	22	22	0	0	0	0	0	0	101	1,070	3,034	8,651	25,718	123	1,140	3,104	8,721	25,766
AS	170	583	583	583	583	501	1,445	2,207	3,251	2,811	0	0	0	0	0	477	904	1,104	1,104	1,104	1,148	2,932	3,894	4,938	4,498
BI	1,390	3,905	10,079	14,258	15,218	0	0	0	0	0	0	0	0	0	0	452	452	452	452	452	1,842	4,357	10,531	14,710	15,670
CH	5,567	18,197	21,798	22,179	27,963	0	0	0	0	0	88	88	88	88	88	120	120	120	120	120	5,775	18,405	22,006	22,387	28,171
DL	5,536	5,959	6,095	6,095	5,390	1,389	2,389	2,389	6,296	11,098	117	117	117	117	117	737	1,171	1,171	1,171	1,171	7,779	9,636	9,772	13,679	17,776
GO	361	385	385	385	385	48	48	452	1,002	1,663	25	25	25	25	25	0	0	0	0	0	434	458	862	1,412	2,073
GU	12,139	14,939	21,863	28,146	34,000	4,436	5,513	8,822	10,852	18,441	552	552	1,952	3,252	5,101	772	772	772	772	772	17,899	21,776	33,409	43,022	58,314
HP	196	196	296	296	296	93	93	93	93	93	36	36	36	36	36	2,469	4,613	5,018	11,650	11,650	2,794	4,938	5,443	12,075	12,075
HY	7,559	8,206	10,688	12,823	14,143	574	574	574	1,601	6,701	107	107	107	1,507	4,307	1,695	1,880	1,880	1,880	1,880	9,935	10,767	13,249	17,811	27,031
JH	4,515	6,095	10,552	12,446	14,235	90	90	90	90	90	0	0	0	0	0	530	530	530	530	530	5,135	6,715	11,172	13,066	14,855
JK	483	483	511	511	511	348	348	348	348	348	77	77	77	77	77	2,082	2,571	6,892	8,874	8,874	2,990	3,479	7,828	9,810	9,810
KE	1,061	1,078	1,078	1,078	1,078	610	968	2,459	4,066	5,648	240	368	368	368	368	1,842	1,942	1,942	2,445	2,445	3,753	4,356	5,847	7,957	9,539
KT	6,150	6,188	6,188	6,188	9,304	454	454	3,581	8,944	11,468	516	728	728	2,128	2,128	3,415	3,415	4,312	4,480	4,480	10,535	10,785	14,809	21,740	27,380
MG	51	133	133	133	133	42	101	271	407	440	0	0	0	0	0	415	543	587	587	884	508	777	991	1,127	1,457
MH	17,191	29,377	32,166	42,394	50,379	3,475	3,475	5,175	8,158	11,392	831	831	831	3,831	7,431	3,238	3,238	3,238	3,238	3,238	24,735	36,921	41,410	57,621	72,440
MN	0	39	39	39	39	75	75	75	75	0	0	0	0	0	0	92	172	1,098	2,024	2,024	167	286	1,212	2,138	2,063
MP	5,309	13,229	18,916	24,393	31,360	396	396	396	2,246	4,336	293	293	293	293	1,693	3,147	3,507	3,507	3,507	3,639	9,145	17,425	23,112	30,439	41,028
MZ	0	59	59	59	59	72	72	72	72	0	0	0	0	0	0	45	140	683	788	788	117	271	814	919	847
NG	0	0	0	0	0	66	159	176	236	198	0	0	0	0	0	57	113	142	142	142	123	272	318	378	340
OR	4,174	9,535	18,875	28,541	39,047	0	0	0	0	0	0	0	0	0	0	2,249	2,249	2,249	2,339	2,339	6,423	11,784	21,124	30,880	41,386
PB	3,735	8,499	9,759	11,329	11,840	291	291	291	291	2,819	194	194	194	194	194	3,508	3,788	3,956	3,956	3,956	7,728	12,772	14,200	15,770	18,809
RJ	5,766	8,896	11,354	15,195	16,961	915	915	1,496	1,815	4,792	707	1,407	2,107	4,207	6,307	1,609	1,976	1,976	1,976	1,976	8,997	13,194	16,933	23,193	30,036
SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	95	515	837	1,239	1,986	95	515	837	1,239	1,986
TN	7,037	12,572	19,563	24,401	27,623	1,651	3,441	7,047	14,273	18,402	1,699	2,345	2,345	2,345	6,596	1,950	1,950	1,950	1,950	1,950	12,337	20,308	30,905	42,969	54,571
TR	0	0	0	0	0	170	896	896	896	858	0	0	0	0	0	72	173	223	223	223	242	1,069	1,119	1,119	1,081
UP	10,675	14,075	24,847	30,022	34,732	606	606	606	3,586	14,309	315	315	315	315	315	2,485	3,386	3,386	3,386	3,386	14,081	18,382	29,154	37,309	52,742
UT	277	371	371	371	371	77	302	302	302	284	32	32	32	32	32	1,564	3,666	4,204	7,879	12,251	1,950	4,371	4,909	8,584	12,938
WB	8,778	9,126	13,926	17,056	28,135	5	61	732	2,304	2,304	0	0	0	0	0	1,761	3,253	3,253	3,253	3,253	10,544	12,440	17,911	22,613	33,692
Total	117,029	185,663	262,223	329,569	402,022	19,942	28,235	44,685	82,684	133,295	6,128	7,814	9,914	19,114	35,114	40,631	52,141	62,548	82,648	105,263	183,730	273,853	379,370	514,015	675,694

Source: Working Group Research (Model Outputs)

Renewable Energy Capacity (MW)					
	RENEWABLE				
STATE	2011-12	2016-17	2021-22	2026-27	2031-32
AP	1,200	5,132	9,584	13,321	17,106
AR	82	111	159	242	343
AS	30	53	94	168	519
BI	74	123	196	323	456
CH	263	329	419	585	719
DL	6	41	330	685	1,078
GO	2	21	276	591	998
GU	3,103	9,422	18,025	31,127	50,114
HP	390	517	727	5,501	5,913
HY	113	197	341	1,972	2,853
JH	209	424	492	612	739
JK	238	1,219	1,781	2,801	3,798
KE	405	711	1,513	1,860	3,157
KT	3,274	6,683	11,700	15,905	25,128
MG	33	56	95	501	683
MH	3,142	3,566	5,722	8,393	15,195
MN	9	47	109	220	544
MP	459	890	1,781	2,267	4,542
MZ	47	57	91	157	236
NG	38	51	86	153	281
OR	100	166	387	453	1,529
PB	290	1,754	2,905	4,772	8,948
RJ	2,069	4,767	9,840	15,448	32,478
SI	2	25	65	139	226
TN	7,395	9,349	12,151	14,447	20,634
TR	18	37	71	137	284
UP	666	1,421	1,604	4,637	5,636
UT	94	213	2,342	3,903	4,228
WB	195	399	739	1,767	2,456
Total	23,946	47,781	83,625	133,087	210,821

Annex III. 4.8

Statewise Net Transmission (GWh)															
	Base Case					Low Case					High Case				
States	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**
AP	10,631	5,418	19,849	40,730	87,802	12,357	1,889	48,381	96,700	1,29,741	12,795	-7,036	-13,184	-18,946	-33,716
AR	-400	-2,021	-9,539	-27,474	-84,257	-411	-1,938	-9,664	-40,462	-49,384	-345	-2,039	-9,304	-39,594	-1,13,613
AS	898	-3,006	-2,308	2,221	9,313	1,241	-3,164	-1,259	1,541	684	555	-1,366	5,892	15,552	30,895
BI	5,322	5,885	-8,478	-18,891	-2,135	4,958	8,250	-2,104	5,775	12,461	5,833	7,205	-22,524	-26,368	11,311
CH	-4,395	-45,692	-65,704	-51,128	-54,733	-5,031	-44,448	-78,519	-66,580	-58,179	-4,708	-49,114	-64,804	-57,831	-51,478
DL	-9,430	-9,595	15,327	26,602	32,170	-7,517	-6,759	5,982	13,565	32,483	-9,915	-10,576	14,460	45,661	59,737
GO	889	2,608	4,384	5,906	8,586	849	2,187	3,550	5,008	5,097	905	2,454	3,936	3,767	3,626
GU	-6,603	7,345	-11,543	-15,349	-12,624	-5,019	9,736	10,130	2,322	9,195	-8,165	-5,974	-63,956	-92,813	-1,61,886
HP	-4,777	-11,759	-10,661	-44,953	-40,893	-5,081	-12,691	-12,943	-44,608	-46,814	-4,705	-11,842	-12,519	-40,757	-44,257
HY	-20,555	56	23,651	38,781	30,559	-15,958	265	18,610	32,322	27,303	-20,152	-1,826	8,880	11,629	-4,678
JH	-1,113	-1,286	-15,332	-13,210	-11,241	-1,752	-2,929	-9,563	-7,713	-4,050	-625	2,429	-30,707	-22,691	-13,578
JK	2,713	7,071	-9,509	-11,661	-5,804	3,275	5,140	-13,079	-18,874	-15,495	2,491	6,735	-3,863	-8,348	-4,350
KE	1,358	6,457	15,049	23,176	34,225	711	4,471	4,970	10,553	20,110	1,536	11,609	27,046	39,243	61,411
KT	-5,153	9,029	17,306	23,338	21,697	-4,232	8,614	23,522	7,698	4,366	-7,678	4,954	-2,425	13,660	40,110
MG	-122	-326	-483	-371	-604	-124	-338	-527	-726	-478	-139	-567	-375	-42	-1,887
MH	-12,306	-1,924	65,105	45,572	51,901	-20,273	28,463	28,492	39,972	37,908	-12,644	-8,918	61,774	62,393	55,966
MN	-121	55	-5,026	-9,905	-9,637	-111	-35	-1,286	-10,545	-10,206	-94	168	-9,070	-8,996	-7,712
MP	11,961	-8,186	-12,967	-11,675	-23,892	11,533	-15,306	-19,947	-7,918	-10,190	13,395	975	2,550	-8,480	10,524
MZ	-68	268	-2,736	-2,867	-2,372	-31	200	-1,385	-3,345	-3,097	-38	169	-2,667	-2,337	-1,749
NG	16	-422	-72	287	456	-1	-386	-321	19	99	24	-545	-35	517	375
OR	4,007	-16,447	-78,892	-1,33,574	-1,74,219	3,318	-17,784	-45,278	-1,00,992	-1,43,431	346	-17,528	-61,381	-1,34,601	-1,34,525
PB	7,670	5,821	20,255	33,427	41,137	5,583	6,360	11,074	14,388	22,556	5,799	504	20,864	33,838	38,393
RJ	6,250	6,763	18,495	6,156	-11,139	7,012	8,901	7,479	2,652	-19,646	5,978	4,450	21,406	5,526	-29,412
SI	-69	-1,569	-3,475	-5,317	-8,601	-51	-1,617	-4,641	-5,785	-8,829	-2	-1,490	-3,285	-4,787	-8,735
TN	635	-10,290	-20,756	-20,928	-31,810	1,716	-8,407	-2,098	-6,459	-4,572	810	-7,532	-29,080	-51,967	-89,020
TR	-348	-5,394	-645	731	1,267	-324	-5,564	-5,477	-3,473	355	-296	-5,166	123	1,283	1,607
UP	11,741	38,513	29,152	80,849	1,41,405	11,574	23,964	26,323	60,757	41,367	16,163	58,649	1,07,104	1,90,819	2,96,393
UT	2,457	-2,319	-2,709	-11,296	-18,522	2,240	-3,243	-5,874	-16,941	-23,004	**2,261**	**-3,484**	**-3,861**	**-13,433**	**-21,009**
WB	-5,779	14,557	17,603	30,783	3,097	-5,581	7,753	13,004	23,490	33,216	-4,025	23,974	42,272	83,536	75,356
Total	-4,691	-10,390	-14,659	-20,040	-28,868	-5,130	-8,416	-12,448	-17,659	-20,434	-4,640	-10,728	-16,733	-24,567	-35,901

Source: Working Group Research (Model Outputs)

Annex III. 4.9

Regionwise Net Transmission (GWh)															
	Base Case					Low Case					High Case				
Regions	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**	**2011-12**	**2016-17**	**2021-22**	**2026-27**	**2031-32**
Northern	-3,932	34,550	84,001	1,17,905	1,68,912	1,128	21,936	37,573	43,262	18,752	-2,080	42,608	1,52,471	2,24,934	2,90,818
Eastern	2,368	1,140	-88,574	-1,40,209	-1,93,099	892	-6,327	-48,582	-85,225	-1,10,633	1,527	14,591	-75,624	-1,04,912	-70,171
Western	-10,455	-45,849	-20,726	-26,675	-30,761	-17,942	-19,368	-56,294	-27,197	-16,170	-11,217	-60,578	-60,500	-92,965	-1,43,247
Southern	7,471	10,614	31,448	66,317	1,11,913	10,551	6,566	74,775	1,08,492	1,49,645	7,462	1,995	-17,643	-18,011	-21,215
Northeast	-145	-10,845	-20,809	-37,377	-85,834	237	-11,225	-19,918	-56,991	-62,027	-333	-9,345	-15,435	-33,617	-92,084
Total	**-4,693**	**-10,390**	**-14,660**	**-20,039**	**-28,869**	**-5,134**	**-8,418**	**-12,446**	**-17,659**	**-20,433**	**-4,641**	**-10,729**	**-16,731**	**-24,571**	**-35,899**

Source: Working Group Research (Model Outputs)

Annex III. 5.1

EXISTING CRUDE OIL PIPELINES

Pipeline Name	Length (km)	Capacity (Mtpa)	Company
Duliajan-Digboi-Bongaigaon-Barauni	1,157	Duliajan-Guwahati (7.0 Mtpa)- Forward; Guwahati-Bongaigaon (5.0 Mtpa) - Forward; Bongaigaon-Guwahati (3.0 MMPTA)- Reverse	Oil India
Mumbai High - Uran - Trunk Pipeline 30'' MUT (Oil)	204	16	ONGC
Heera - Uran - Trunk Pipeline 24'' HUT (Oil)	81	12	ONGC
30'' BUT (Oil)	203	18	ONGC
Kalol-Nawagam-Koyali	51	3	ONGC
Nawagam-Koyali	78	5	ONGC
MHN-NGM Trunk Line	77	2	ONGC
CTF, Ank to Koyali Oil Pipeline (AKCL) #	98	2	ONGC
Lakwa-Moran Oil Line	18	2	ONGC
Geleki-Jorhat Oil Line	48	2	ONGC
Borholla- Jorhat	42	1	ONGC
NRM to CPCL	6	1	ONGC
KSP-W GGS to TPK Refinery	14	0	ONGC
GMAA EPT to S. Yanam Unloading Terminal	4	0	ONGC
Salaya-Mathura	1,870	21	Indian Oil
Paradip-Haldia-Barauni	1,312	11	Indian Oil
Mundra-Panipat	1,194	8.4	Indian Oil
Mundra-Bhatinda Pipelines	1,014	18	HPCL
Vadinar Bina Crude Pipeline	935	6	BPCL
Mangala Development Pipeline (MDP)*	670	7.5	

Source: Ministry of Petroleum and Natural Gas

EXISTING PRODUCT PIPELINES

Pipeline Name	Length (km)	Capacity (Mtpa)	Company
Barauni-Kanpur	745	3.5	Indian Oil
Guwahati-Siliguri	435	1.4	Indian Oil
Haldia-Barauni	525	1.25	Indian Oil
Haldia-Mourigram-Rajbandh	277	1.35	Indian Oil
Koyali-Ahmedabad	116	1.1	Indian Oil
Koyali-Sanganer	1056	4.1	Indian Oil
Mathura-Delhi	147	3.7	Indian Oil
Panipat-Ambala-Jalandhar	434	3.5	Indian Oil
Panipat-Delhi	182		Indian Oil
Panipat-Bhatinda	219	1.5	Indian Oil
Digboi-Tinsukia	75	1	Indian Oil
Mathura-Tundla	56	1.2	Indian Oil
Mathura-Bharatpur	21	1.2	Indian Oil
Panipat-Rewari	155	1.5	Indian Oil
Chennai-Trichy-Madurai	683	2.3	Indian Oil
Koyali-Dahej	103	2.6	Indian Oil
Amod-Hazira	94	2.6	Indian Oil
Koyali-Ratlam	265	2	Indian Oil
Chennai-Bangalore	290	1.45	Indian Oil
Bijwasan-Panipat Naphtha	111	0.8	Indian Oil
Chennai ATF	95	0.18	Indian Oil
Bangalore ATF	36	0.66	Indian Oil
NNPL (Dockline from IBP Narimanam to Nagpattinam)	7	0.368	Indian Oil
Mumbai-Bijwasan	1,389	5.9	BPCL
BCPL (Pipeline from JV Refinery)	257	2.8	BPCL
(BPCL JV) Petronet CCK	293	3.3	BPCL
Mundra-Delhi Pipeline	1,054	3.84	HPCL
Mumbai-Pune-Solapur Pipeline	508	3.67	HPCL
Vizag-Vijayawada-Secunderabad Pipeline	572	5.38	HPCL
Mangalore-Hasan-Bangalore Pipeline	362	2.1	HPCL
Numaligarh-Siliguri*	654	1.7	OIL

Annex III. 5.3

ESTIMATED RAW MATERIAL REQUIREMENT BASED ON METALLIC BALANCE FOR THE PROJECTED CRUDE STEEL PRODUCTION

Estimated Raw Material Requirement Based on Metallic Balance for the Projected Crude Steel Production,								
Categories	**2016-17**		**2021-22**		**2026-27**		**2031-32**	
	Usage T/T	Qty (Mn T)	Usage T/T	Qty (Mn T)	Usage T/T	Qty (Mn T)	Usage T/T	Qty (Mn T)
1. Crude Steel		**126**		**219**		**353**		**532**
Metallics for Crude Steel,	**1.12**	**141**	**1.10**	**241**	**1.10**	**389**	**1.09**	**580**
of which								
Hot Metal	70%	98	65%	156	65%	253	60%	348
Sponge Iron	20%	28	20%	48	15%	58	15%	87
Scrap	10%	14	15%	36	20%	78	25%	145
2. Pig Iron		**9**		**12**		**18**		**25**
3. Total Metallics		**150**		**253**		**407**		**605**
Raw Material								
a) Iron Ore	1.60	217	1.60	346	1.60	526	1.60	736
b) Coking Coal	0.80	86	0.80	135	0.75	203	0.75	280
c) PCI	0.10	11	0.10	17	0.15	41	0.15	56
d) Non-coking Coal	1.40	39	1.40	67	1.40	82	1.40	122
e) Others		118		188		284		398
Total Raw Materials		**471**		**754**		**1135**		**1592**
Total Raw Materials & Scrap		**485**		**790**		**1213**		**1737**
Specific Consumption of Raw Materials & Scrap (T/TCS)		**4**		**4**		**3**		**3**

Annex III.6.1 Additional Augmentation Required by State

(All numbers are in km)

State	Multiple Lines					Total	GC	Total
	4th line	5th &6 th line	6th line	Doubling	Quadrupling			
AP	0	0	0	1,926	1,704	3,629	0	3,629
AS	0	0	0	1,440	0	1,440	0	1,440
BI	0	0	0	951	762	1,712	95	1,807
CH	0	0	0	336	94	430	0	430
DL	0	0	0	0	74	74	0	74
GUJ	0	0	0	980	346	1,326	53	1,379
HAR	42	0	0	137	286	465	0	465
HP	0	0	0	0	0	0	155	155
JH	91	0	0	318	342	752	0	752
KAR	0	0	0	1,211	37	1,248	0	1,248
KER	0	0	0	158	182	340	0	340
MAH	0	0	18	1,631	1,260	2,909	244	3,153
MP	0	0	0	702	1,683	2,385	0	2,380
OR	0	0	0	345	1,192	1,537	0	1,537
PB	0	0	0	620	242	861	10	871
RAJ	0	0	0	1,066	426	1,491	308	1,799
TN	9	21	0	378	446	855	0	855
UK	0	0	0	79	48	127	0	127
UP	84	0	0	2,462	645	3,191	0	3,191
WB	91	8	0	480	541	1,120	0	1,120
Total	**317**	**29**	**18**	**15,220**	**10,310**	**25,894**	**864**	26,754

Annex III. 6.2

Costs for Additional Rolling Stock and Terminals			
per Mtpa of increased transport of coal (in Rs crore)			
Items	**Unit Cost**	**Number Required per Mtpa**	**Cost per Mtpa**
Rakes	15	5	75
Locomotives	8	5	40
Maintenance	10% of rolling stock cost		11.5
Terminals	100	2/10	20
TOTAL			146.5

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