Five R's

A cross-sectoral landscape of Just Transition in India

iFOREST
INTERNATIONAL FORUM FOR ENVIRONMENT, SUSTAINABILITY & TECHNOLOGY

Five R's

A cross-sectoral landscape of Just Transition in India

iFOREST | INTERNATIONAL FORUM FOR ENVIRONMENT, SUSTAINABILITY & TECHNOLOGY

Authors: Chandra Bhushan and Srestha Banerjee

Cover design: Raj Kumar Singh

Design and Layout: Raj Kumar Singh

We would like to thank The Children's Investment Fund Foundation (CIFF) for their support in developing this study.

June 2021

ISBN: 978-81-949354-1-4

Citation: Chandra Bhushan and Srestha Banerjee. (2021). Five R's: A cross-sectoral landscape of Just Transition in India, International Forum for Environment, Sustainability & Technology (iFOREST), New Delhi.

Published by:

Sustainability Innovation and Advisories Private Limited

G-60, Nizamuddin (West), Delhi - 110013

Printed at: Print Edge Inc.

Contents

List of Tables

5. Iron and Steel

6. Cement

7. Road transport

8. Fertilizers

List of Figures

List of Maps

6. Cement

7. Road transport

8. Fertilizers

Abbreviations

ACM	Auto Component Manufacturer
ASI	Annual Survey of Industries
BAT	Best Available Technologies
BAU	Business-as-Usual
BCCL	Bharat Coking Coal Limited
BOF	Basic Oxygen Furnace
BORL	Bharat-Oman Refinery Limited
BPCL	Bharat Petroleum Corporation Limited
CAGR	Cumulative Annual Growth Rate
CCL	Central Coalfields Limited
CCUS	Carbon Capture Utilisation and Storage
CDQ	Coke Dry Quenching
CEA	Central Electricity Authority
CGD	City Gas Distribution
CIL	Coal India Limited
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CPCL	Chennai Petroleum Corporation Limited
CPP	Captive Power Plants
CPSE	Central Public Sector Oil and Gas Enterprises
CRF	Controlled-Release Fertilizers
DMF	District Mineral Foundation
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
ECL	Eastern Coalfields Limited
EV	Electric Vehicles
GHG	Greenhouse gas
GST	Goods and Services Tax
GWP	Global Warming Potential
HCV	Heavy Commercial Vehicle
HMEL	HPCL-Mittal Energy Limited
HPCL	Hindustan Petroleum Corporation Limited
HSD	High Speed Diesel
IBM	Indian Bureau of Mines
IC	Internal Combustion
IEA	International Energy Agency
IFFCO	Indian Farmers Fertiliser Cooperative Limited
IOCL	Indian Oil Corporation Limited
IVC	India Vision Case
JV	Joint Venture
LCV	Light Commercial Vehicle
LDO	Light Diesel Oil
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MCL	Mahanadi Coalfields Limited
MCV	Medium Commercial Vehicle
MRPL	Mangalore Refinery and Petrochemicals Limited
NCL	Northern Coalfields Limited
NIC	National Industrial Classification
N_2O	Nitrous Oxide
NRL	Numaligarh Refinery Limited
NSS	National Sample Survey
NSSO	National Sample Survey Organisation
NTPC	National Thermal Power Corporation
NUE	Nitrogen Use Efficiency
OC	Open Cast
ONGC	Oil and Natural Gas Corporation
PEM	Proton Exchange Membrane
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped Natural Gas
PSU	Public Sector Undertaking
PV	Photovoltaic
RINL	Rashtriya Ispat Nigam Limited
RIL	Reliance Industries Limited
RE	Renewable Energy
SAIL	Steel Authority of India Limited
SCM	Supplementary Cementitious Materials
SDS	Sustainable Development Scenario
SCCL	Singareni Collieries Company Limited
SECL	South Eastern Coalfields Limited
SOEC	Solid Oxide Electrolysis Cells
STEPS	Stated Policies Scenario
TPP	Thermal Power Plant
TRT	Top-pressure Recovery Turbines
TRL	Technology Readiness Level
2W	Two wheeler
3 W	Three wheeler
UG	Underground
UT	Union Territory
VAT	Value Added Tax
WCL	Western Coalfields Limited

Summary for Stakeholders

Just Transition approach will be determined by the energy transition pathways

India's trajectory for energy transition will determine the policy and planning approach for just transition. Two recent modelling studies on net-zero emissions pathways for India provide a glimpse of possible trajectories to reduce fossil fuels over the next three to four decades.

a. India Energy Outlook (IEA, 2021): This India-specific report projects India's energy systems development till 2040. One of the scenarios considered in the report is the Sustainable Development Scenario (SDS). The SDS essentially explores how India could mobilise an additional surge in clean energy investment to produce an early peak and rapid subsequent decline in emissions to reach net-zero by the mid-2060s. Under this scenario, India's coal demand will have to halve by 2040 and reduce by 85% by 2050. Natural Gas can increase three-fold by 2040 and be 2.5 times the 2019 levels in 2050. Oil can increase by 15% by 2040 and then reduce by 30% by 2050.

Table 1: Net-zero pathway by mid-2060

Fossil-fuel sector	SDS			
	2019	2030	2040	2050*
Coal demand (Mtce)	590	454	298	100
Oil demand (mb/d)	5.0	6.2	5.8	3.48
Natural gas demand (bcm)	63	144	210	150

* IEA has provided data only till 2040. For 2050, an extrapolation has been done assuming that coal will reach zero by 2055, oil by 2065, while gas use in 2065 is similar to 2020. At these consumption levels, India will reach net-zero in 2065.

b. India: Transforming to a net-zero emissions energy system (TERI and Shell, 2021): This report explores the pathways to steer the domestic energy system towards net-zero emissions by 2050. The report, which remains cautiously optimistic about achieving a net-zero emissions energy system by 2050, heavily relies on technological advancements and policy support to achieve it. However, the pathways in this report project less reduction in coal demand (by 60%) and more reduction in oil use (60%) by 2050 compared to the IEA report. The natural gas use increase, however, is the same — three-fold by 2050 compared to current levels.

Table 2: Net Zero pathway by 2051

Primary Energy requirement (Mtoe)	2021	2051
Coal	505	216
Oil	222	89
Gas	53	149
Nuclear	19	45
Hydro	21	33
Solar	93	876
Wind	27	548
Bio/Waste/other	92	204

Source: TERI and Shell, 2021

From the two modelling studies, what can be concluded is that the transition pathways depend on assumptions on factors such as cost, technology, energy security, etc. What is, however, clear is that in any net-zero scenario, coal use will have to go down sharply, while gas use can increase three to four-folds. Oil consumption will also have to go down, but it will depend on the interplay of cost, alternatives, and energy security.

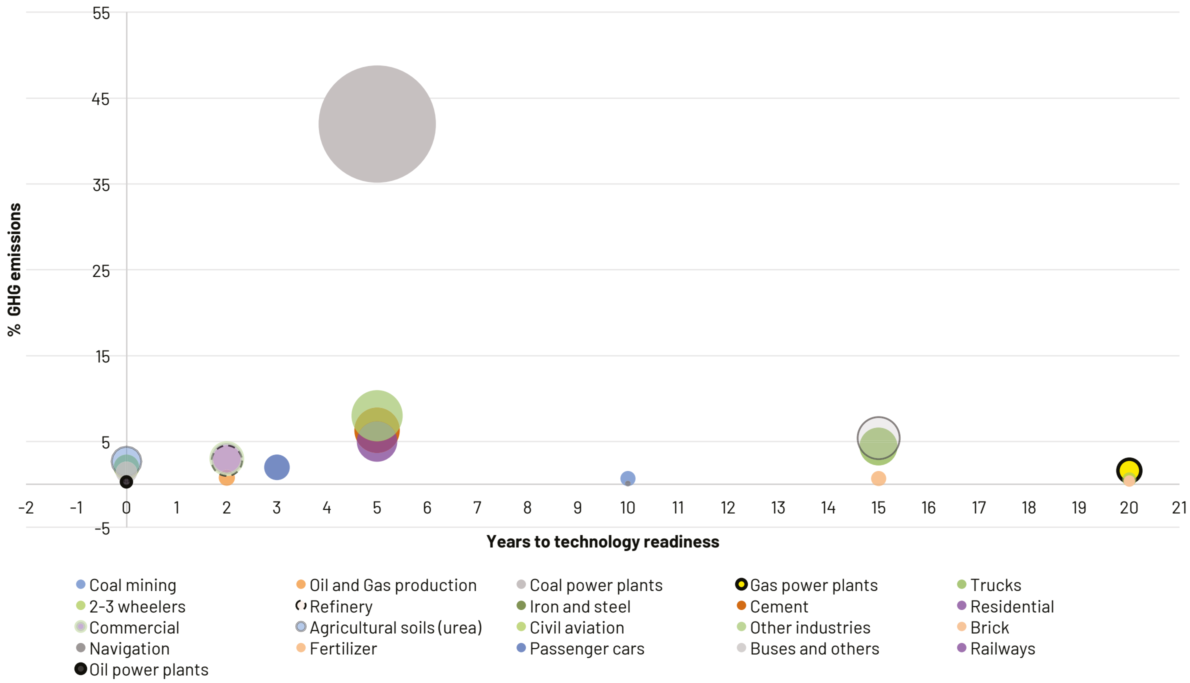
Therefore, policy and planning for transition in the coal sector should be prioritised from a just transition perspective.

Just transition should be prioritised for sectors with significant emission reduction potential and competitive alternate technologies

The assessment of greenhouse gas (GHG) emission reduction potential and availability of competitive alternate technologies suggest that the sectors that need to be prioritised for a just transition include coal mining, thermal power plants, road transportation, other industries, and agriculture soil (urea use). These sectors collectively emit 64% of India's GHG, and 90% of technologies required for the transition in these sectors will be commercially available in the next five years (Figure 1 and Annexure 1). Coal mining, thermal power plants and road transportation are likely to see disruptive changes both in terms of job losses and skill requirements during this decade. Other industries and agriculture soil, on the other hand, will see a progressive transition. Most other coal-dependent sectors such as steel, cement, and fertilizer will need to start planning for a just transition only in the 2030s.

Some transition is already underway in residential, commercial, and agriculture sectors, but these will have to be upscaled significantly. In agriculture, for example, reduction in urea use (which contributes to N_2O emissions) is being promoted by adopting neem-coated urea and promoting other nutrients. But this has not led to a significant reduction in use. Similarly, energy efficiency is being promoted in residential and commercial sectors, but the best-in-class technologies in building, cooling, and heating sub-sectors are not being adopted. Just transition in these sectors is mainly about progressive enhancement in efficiency, training, and capacity building.

Figure 1: Emissions vs Technology readiness



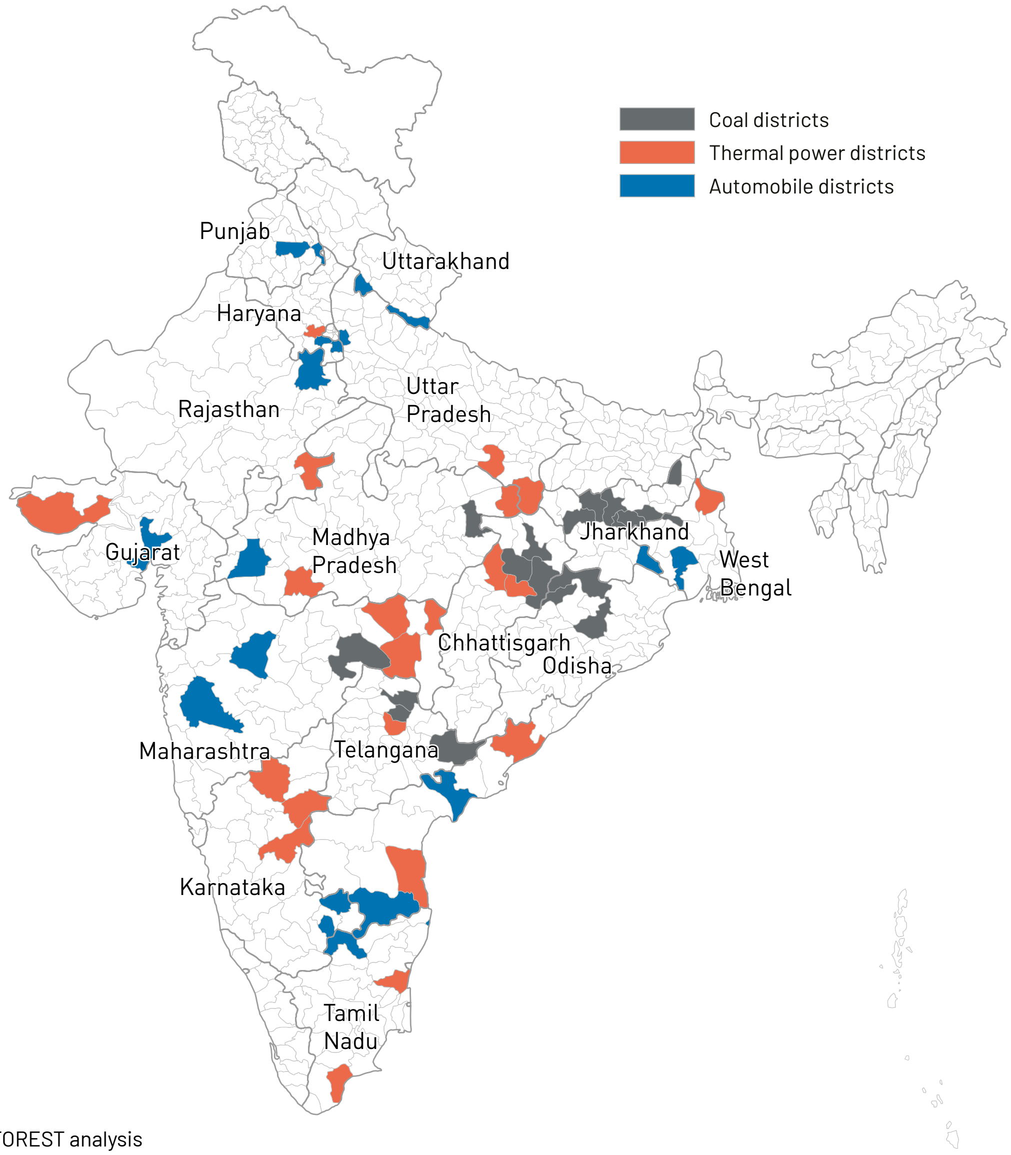
Source: iFOREST analysis

60 districts in 16 states should be prioritised for just transition

There are 120 districts (out of the 718 districts) in the country with a sizeable presence of fossil fuel or fossil-fuel dependent industries – coal mining, oil and gas production, thermal power plants, refineries, steel, cement, fertilizer (urea), and automobile. These districts have a population of about 330 million, or about 25% of the country's population.

Of the 120 districts, there are 60 districts where just transition should be prioritised as these districts account for 95% of coal and lignite production, 60% of thermal power capacity, and 90% of automobile and automobile component manufacturing. Jharkhand has the highest number of districts (8), followed by Maharashtra (6), and Chhattisgarh and Karnataka (5 each). About one-third of the districts are concentrated in the coal belt of Jharkhand, Chhattisgarh, Odisha, and West Bengal (Map 1).

Map1: The transition geography of this decade



Source: iFOREST analysis

Note: Many districts have both coal mining and coal-based power plants. For simplicity, the district that is comparatively in a higher ranking for coal mining is depicted as a coal mining district, and that with a higher ranking for thermal power capacity is depicted as a thermal power district.

Over 20 million workers are currently engaged in fossil-fuel and fossil fuel dependent industries; they will need job replacement and reskilling

The Indian economy is dominated by informal workers, with more than 90% of the workforce accounted for by the informal economy.[1] Most fossil fuel sectors reflect this dominance of informality (*Box 1: Defining informal workers in India*).

There is no consolidated data on employment in fossil fuel and fossil fuel-dependent sectors. Scattered data (typically formal manpower estimates) are available from various sources, including the Annual Survey of Industries (ASI), company-wise annual reports, publications of ministries, and various government departments. These data have been collectively considered to arrive at the employment situation in these sectors. To estimate the formal and informal division, the NSSO 68th round of survey on employment and unemployment situation of India, which provides an estimation of the proportion of formal and informal employment in various industries and sectors (as per NIC 2008 classification), has been used.[2]

Our estimates show that at least 21.5 million people work in fossil fuels and fossil fuel-dependent sectors (Table 3). Automobile, iron and steel, and coal mining are the biggest employers. In all of these sectors, the informal workforce is nearly four times the formal workforce.

Table 3: Estimated workforce (in million)

Sectors	Informal Employment	Formal Employment	Total Employment
Coal mining	1.8	0.8	2.6
Coal-based thermal power (1)	0.05	0.13	0.18
Iron and Steel	2.6	0.3	2.9
Cement	1.2	0.2	1.4
Oil and Gas, excluding refineries (2)	NA	0.12	0.12
Refineries	0.08	0.04	0.12
Fuel Retail	0.96	0.14	1.10
LPG distribution	0.01	0.09	0.10
Fertilizer (3)	0.2	0.02	0.22
Automobile (4)	NA	NA	12.8
Total	**6.9**	**1.8**	**21.5**

Sources: iFOREST estimates based on annual reports, Annual Survey of Industries and NSSO 68th round of survey[3].

Explanatory notes: (1) Excluding fly ash handling and processing. (2) This is formal employment in oil and gas companies. The total employment is likely to be higher, due to the large-scale use of contract workers. (3) Only urea manufacturing plants, which are directly dependent on fossil fuels for feedstock. (4). Division of formal and informal workers not available. Includes employment in servicing and dealership.

There is a difference in the spatial distribution of employment. While oil and gas and automobile employment are spread across the country, coal and coal-related industries employment is concentrated in a relatively smaller number of districts.

In some districts, the coal sector's employment is the most important contributor to the district's economy. For example, in the Korba district of Chhattisgarh, over 7.2% of the district population is formally employed by the coal-mining and coal-based power plants. However, the overall employment is far higher than this (nearly three times, considering the informal workers employed in coal mining and coal-based power). A similar case is observed for Dhanbad and Chatra districts of Jharkhand, and Angul and Jharsuguda districts of Odisha, the other key coal regions.

Defining informal sector and worker in India

Informal worker/employment: These include unorganised workers working in the unorganised sector or households, excluding regular workers with social security benefits provided by the employers, and the workers in the formal sector without any employment and social security benefits provided by the employers.

Informal sector: The informal sector may be broadly characterised as units engaged in producing goods or services with the primary objective of generating employment and incomes for the persons concerned. These units typically operate at a low level of organization, with little or no division between labour and capital as factors of production, and on a small scale. Labour relations - where they exist - are based mostly on casual employment, kinship, or personal and social relations rather than contractual arrangements with formal guarantees.

Informal economy: The informal sector and its workers and informal workers in the formal sector constitute the informal economy.

Indirect employment: This can be defined as contract workers, who are hired, supervised, and remunerated by a contractor who, in turn, is compensated by the establishment.

Source: Labour Bureau, Ministry of Labour and Employment. (2015). Employment in Informal Sector and Conditions of Informal Employment. Volume IV, 2013-14. Government of India.

Just transition will involve Five R's

A just transition in India will need policy and planning for five key elements:

1. **R**estructuring of the economy and industries;
2. **R**epurposing of land and infrastructure;
3. **R**eskilling existing and skilling new workforce;
4. **R**evenue substitution and investments in just transition; and,
5. **R**esponsible social and environmental practices.

All of these need to be considered appropriately in a sectoral and region-specific manner to ensure targeted interventions and achieve just socio-economic and environmental outcomes.

1. Restructuring of the economy and industries

Most of the top coal mining districts are mono-industry districts, which has created a dominance of coal in the economic landscape of these regions. In these districts, the economy is heavily reliant on coal mining, power plants, and coal-dependent industries. This has stymied the development of other sectors and undermined the scope of economic diversification. It has also affected people's psyche in these regions, creating a sense of 'perceived dependence'. As a result, most economic activities and income opportunities in these regions can be assumed to be somehow influenced by the mono-industry. Therefore, a critical component of just transition in India will be restructuring the economy and industries of these regions.

A well-designed industrial restructuring plan can facilitate a transition with minimum economic disruption. This will involve developing appropriate industrial policies by the concerned State Governments and district development plans in consultation with local institutions.

Besides developing low-carbon industries and attracting necessary investments for them, a particular focus of the economic and industrial restructuring should be harnessing the potential of local resources. In many fossil fuel districts, there is huge potential to boost the local economy and create sustainable industries based on agricultural and forest products, aquaculture, dairy, and sustainable tourism. For instance, on average, India's top coal mining districts have over 31% forest cover, which is 10% higher than India's average. At the same time, many of the top coal districts have significant agricultural potential, with cultivable areas ranging between 30%-45%. However, much of this potential remains neglected due to poor market support and linkages for agriculture and forest products or inadequate investments in these sectors.

2. Repurposing of land and infrastructure

Reclamation and repurposing of mining and industrial lands (brownfields) and associated infrastructure will be important for economic diversification and socio-economic development in fossil fuel regions.

An estimated 0.45 million hectares (ha) of land is available with coal mining and major coal allied industries, including coal-based power, iron and steel, and cement.[4] In fact, only coal mines and power plants account for about 0.3 million ha of land. In some districts, coal mining companies hold as much as 10% of the geographical area.[5]

The available land provides a massive scope of creating immediate and long-term economic opportunities. In the short term, land reclamation and redevelopment will require the engagement of large numbers of skilled and unskilled workers, creating direct employment. Moreover, well-planned infrastructure projects with complementary investments can also have a far-reaching benefit for the local economy.[6] However, certain reforms would be required in the land acquisition and reclamation laws to allow for the smooth repurposing of land and infrastructure. This includes modifications in the mine reclamation, land use change, and ownership laws.

3. Reskilling existing and skilling new workforce

The review of transition scenarios for each fossil fuel-related sector suggests three primary modes of impact on the workforce. These include:

- Job loss due to declining production and eventually closing down of operations;
- Retraining and reskilling of the existing workers due to changes in production processes or repurposing of facilities; and,
- Skilling of the new workforce to meet the requirements of new zero-carbon industries.

The extent of job loss and the requirement of reskilling and skilling is related to the nature of operations of these sectors and the distribution of workforce (such as formal and informal), including their skills levels. A review of job loss versus reskilling in various sectors is elaborated in Annexure 2.

It can be inferred from the job loss versus reskilling matrix that sectors that will experience job loss are coal mining, coal-based power, and refineries. This is because there will be progressive phasing down of operations of these sectors in the coming decades. In the rest of the sectors, a well-planned reskilling and skilling programme will avoid job losses. Of course, job losses can happen for informal workers in all sectors, but a timely intervention of reskilling and retraining can help them to get readily absorbed, as there is no overall scaling down of activities or net decrease of production in the coming years in sectors other than coal mining and thermal power.

For coal mining, the challenge of job loss is far higher than coal-based power plants or refineries, considering the predominance of the informal workforce. In addition to this, there is a subsistence coal economy in many of the old coal mining regions, particularly in the coal-mining districts of Eastern India. In these regions, stretching from Raniganj coalfields in West Bengal to the Jharia and North Karanpura coalfields of Jharkhand, thousands of people earn a living by manually gathering and selling coal in local markets.[7]

For job loss, the following policy and planning interventions would be required: creating alternative livelihood opportunities through industrial restructuring, supporting entrepreneurship, and harnessing the local resource base; repurposing and redeveloping the brownfield areas (as discussed above); providing pensions, compensations, and transition packages; and reskilling and retraining of particularly the younger workforce.

Investments in reskilling and skilling will be necessary for the workforce in all sectors. This is particularly important for the young formal and informal workers. Moreover, there will be a huge requirement in all low/

zero-carbon industries for skilled jobs, such as in factories for solar panels, EVs, battery, and other equipment manufacturing.

For reskilling and skilling to happen, having proper skilling policies at the Government and company levels will be important. This, in fact, is a prerequisite for just transition, particularly considering the predominance of the informal workforce, who are primarily unorganised.

4. Revenue substitution and investments in just transition

A critical issue for just transition is the substitution of public revenue from fossil fuel and related sectors. Coal, Oil, and Gas collectively contribute 18.8% of the total revenue receipts of the Central Government and about 8.3% of the total revenue receipts of the State Government.[8] About 91% of revenue contribution is from the oil and gas sector; coal contributes only about 9%. Therefore, from a just transition perspective, revenue substitution from the oil and gas sector will be a far bigger challenge than the coal sector. Also, as the oil and gas phase down is likely to happen only in the 2030s, revenue substitution is not an immediate concern and can be spread out over the next two to three decades.

The revenue loss from coal mining, however, will affect the State Governments. For states, the main source of revenue from coal is royalty and District Mineral Foundation (DMF) contributions. In most top coal states, such as Jharkhand and Chhattisgarh, the share of royalty, DMF, and taxes from coal mining to the total revenue receipt is about 5%-6%. In other coal-producing states, such as West Bengal, the contributions are far lower, about 1%-1.5%. In fact, some coal-producing states earn more by taxing petrol and diesel than by taxing coal (Table 4).

Table 4: Sales taxes from petrol and diesel, and direct revenue from coal mining (2019-20)

State/UT	Sales Tax/VAT from CPSEs (₹ Billion)		Coal mining taxes and revenues of PSUs to state (₹ Billion)
	Petrol	Diesel	
Chhattisgarh	12.67	24.84	32.21
Jharkhand	8.97	20.19	39.92
Madhya Pradesh	28.71	38.75	34.10
Odisha	15.79	38.39	29.11

Source: iFOREST analysis based on data of Petroleum Planning and Analysis Cell for CPSEs, and respective company annual reports and accounts for PSUs.; Note: Central Public Sector Oil and Gas Enterprises

Still, the public revenue substitution must be planned carefully. This is also because states will have to play a role in just transition financing through public revenue. In this context, both DMF and GST compensation tax is extremely important.

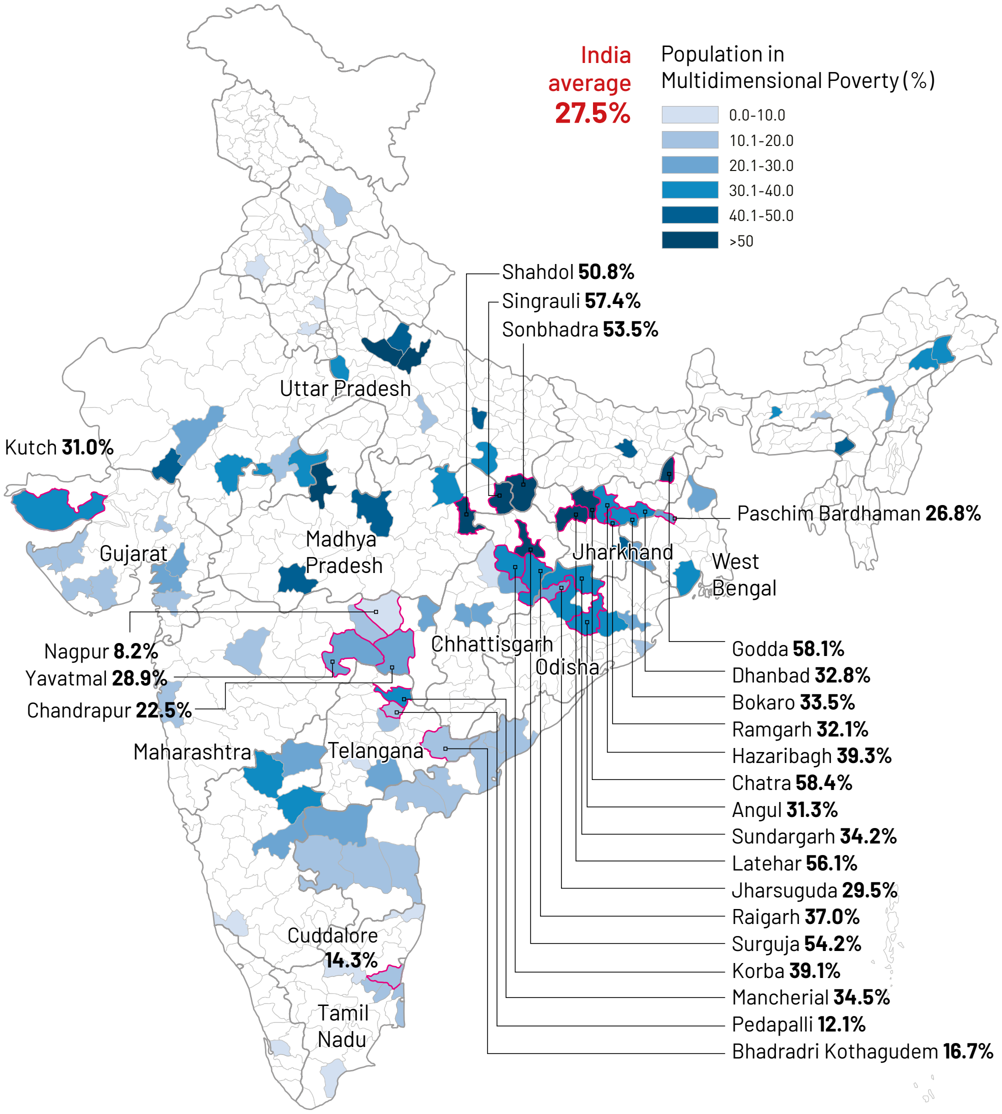
The most significant tax on coal is the GST compensation cess (originally instituted as the coal cess to fund green energy transition), levied at ₹ 400 per tonne on the dispatch of coal and lignite. The GST compensation cess in 2019-20 was an estimated ₹ 400 billion. This is almost double the revenues (taxes, royalty, and DMF) that states get from coal. However, the GST compensation cess will lapse in 2022. Post this, there is an opportunity to reverse this to coal cess and use it for just transition in coal mining areas. Similarly, DMF funds should be aligned to just transition investments, which currently have a cumulative accrual of about ₹ 184 billion in the coal-mining districts.

5. Responsible social and environmental practices

Just transition provides us with an opportunity to create a better world than what we have today. Resource extraction has led to large-scale displacement and deprivation for local communities in India. The use of these resources, on the other hand, has led to pollution and ecological destruction.

'Resource curse' is a reality in the coal districts of India. More than 50% of the population in most top coal districts are multidimensionally poor, suffering from poor health, education, and living standards; this is twice India's average of 27.5% (Map 2). Additionally, districts with the dominance of coal mining, power plants, steel, cement, and refineries are critically polluted in terms of air, water, and soil pollution. Coal mining is also responsible for about half of all the forestland diverted for mining, affecting forest-based livelihoods, an important source of income for marginalised communities.[9]

Map 2: Distribution of multidimensional poverty

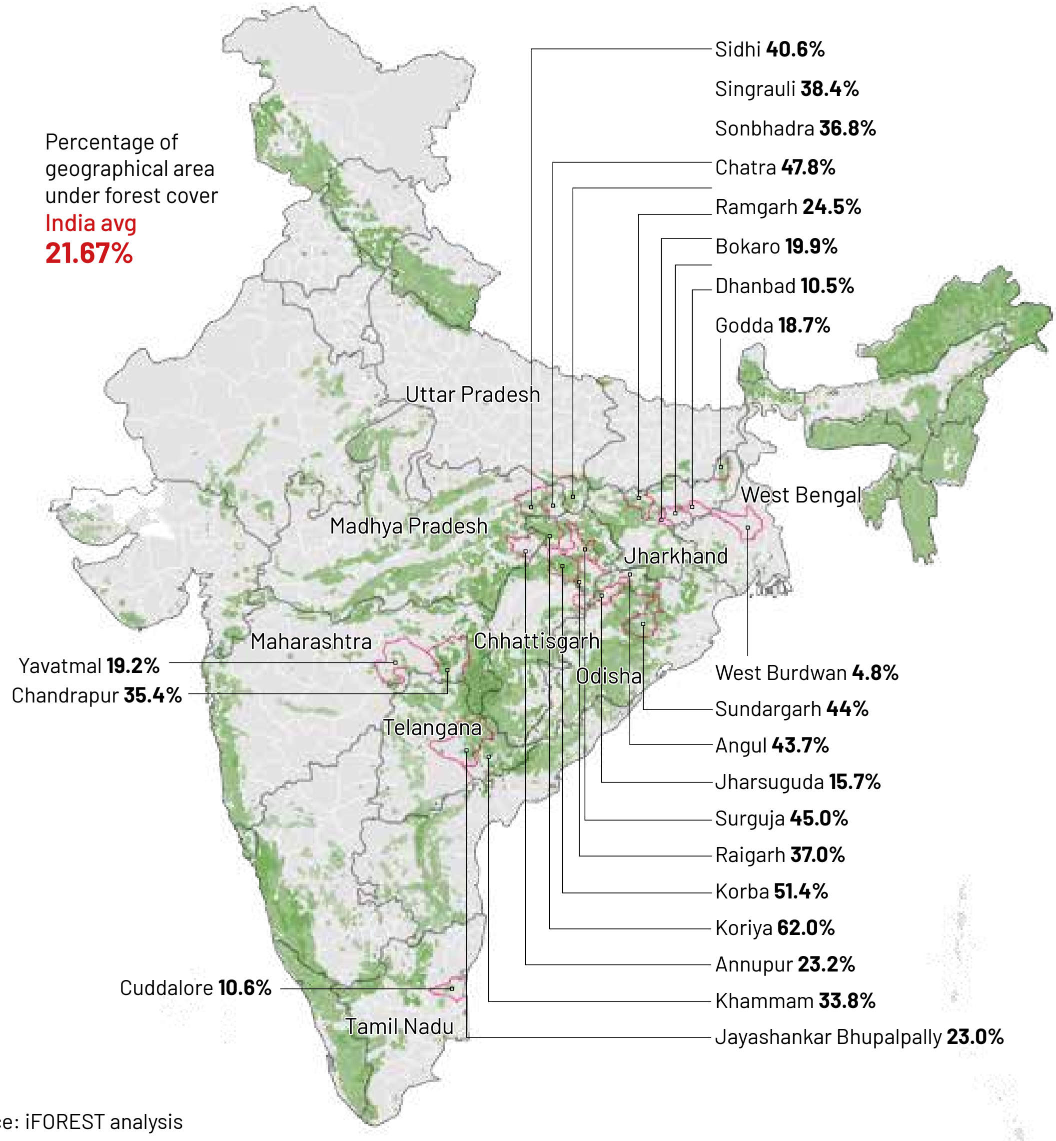


Source: iFOREST analysis; Data adopted from India country-level analysis of Oxford Poverty and Human Development Initiative.

But we have an opportunity to reverse this trend by adopting better social and environmental policies and practices. Just transition planning in the coming years allows us to develop a new 'environmental and social contract' between the people, the government, and the private sector. The new social contract must ensure inclusive decision-making, poverty alleviation, fairer income distribution, and investments in human development and social infrastructure. The new environmental contract should be about ecological protection and restoration, which will also contribute to the enhancement of sustainable livelihood and income opportunities.

There is already a huge untapped potential for this. For example, the average forest cover in coal mining districts is nearly double the country's average (Map 3). Similarly, there are huge tracts of agricultural land in these areas whose productivity can be improved through investments in irrigation and watershed management practices.[10]

Map 3: Forest cover in top coal districts



Source: iFOREST analysis

To conclude, just transition will be a strategic process that must be planned carefully and rolled out over the next few years. This should be done considering the opportunities for transition in various sectors, the geographies which are particularly vulnerable to the closure of operations and subsequent job loss, distribution of the workforce (formal and informal), and the overall resilience of the local communities and the regions dependent on fossil-fuel and allied sectors.

The assessment clearly shows that a transition by no means can happen in one go for all sectors, nor should it be planned in that manner. Therefore, a road map must be developed for the coming decades aligning with the emission reduction targets and considering the opportunities at hand to usher in a transformative change that is inclusive, just, and viable.

Introduction

Rapid decarbonization has become necessary to limit global warming to 1.5°C to avoid catastrophic impacts of climate change. Transformative changes and decisive actions will be required to accelerate decarbonization. This will involve decisions on production and use of fossil fuels, transformation of energy-intensive industries, and re-invention of supply chains. The latest report of the International Energy Agency (2021) – *Net Zero by 2050: A Roadmap for the Global Energy Sector* – has underscored the scale and urgency of action that must be undertaken by policy makers, industries, and various other actors, to ensure that in the next three decades the world can remain on track to meet the goals of the Paris Agreement (2015).

However, the road to the net-zero target must also be socially and environmentally responsible and inclusive. Therefore, the Paris Agreement has emphasised on the importance of a 'just transition'. For India, a just transition becomes extremely important as we do not have a predominantly formal economy or resources for social support like the developed countries, where just transition is largely about reskilling and providing employment and support to formal workers. The informal nature of the Indian economy coupled with large-scale deprivation and development deficit, demands a much more holistic approach to a just transition in India. In other words, a just transition in India will entail 'structural changes' and require a broad-based socio-economic transition, not just reskilling and support systems for formal workers.

Developing a just transition roadmap and plan(s), therefore, will require an elaborate exercise and a deliberative bottom-up process involving all stakeholders. It will require mapping out each of the fossil fuel and allied industrial sectors with respect to their contribution to greenhouse gas (GHG) emissions, the opportunities for substitution, a viable timeframe for transition, the regional impacts, and the potential impact on the workers (formal and informal) with respect to job-loss or skill development.

In this report, we evaluate the fossil fuel sectors and the following key allied industrial sectors :

1. Thermal power
2. Iron & Steel
3. Cement
4. Fertiliser
5. Road Transport

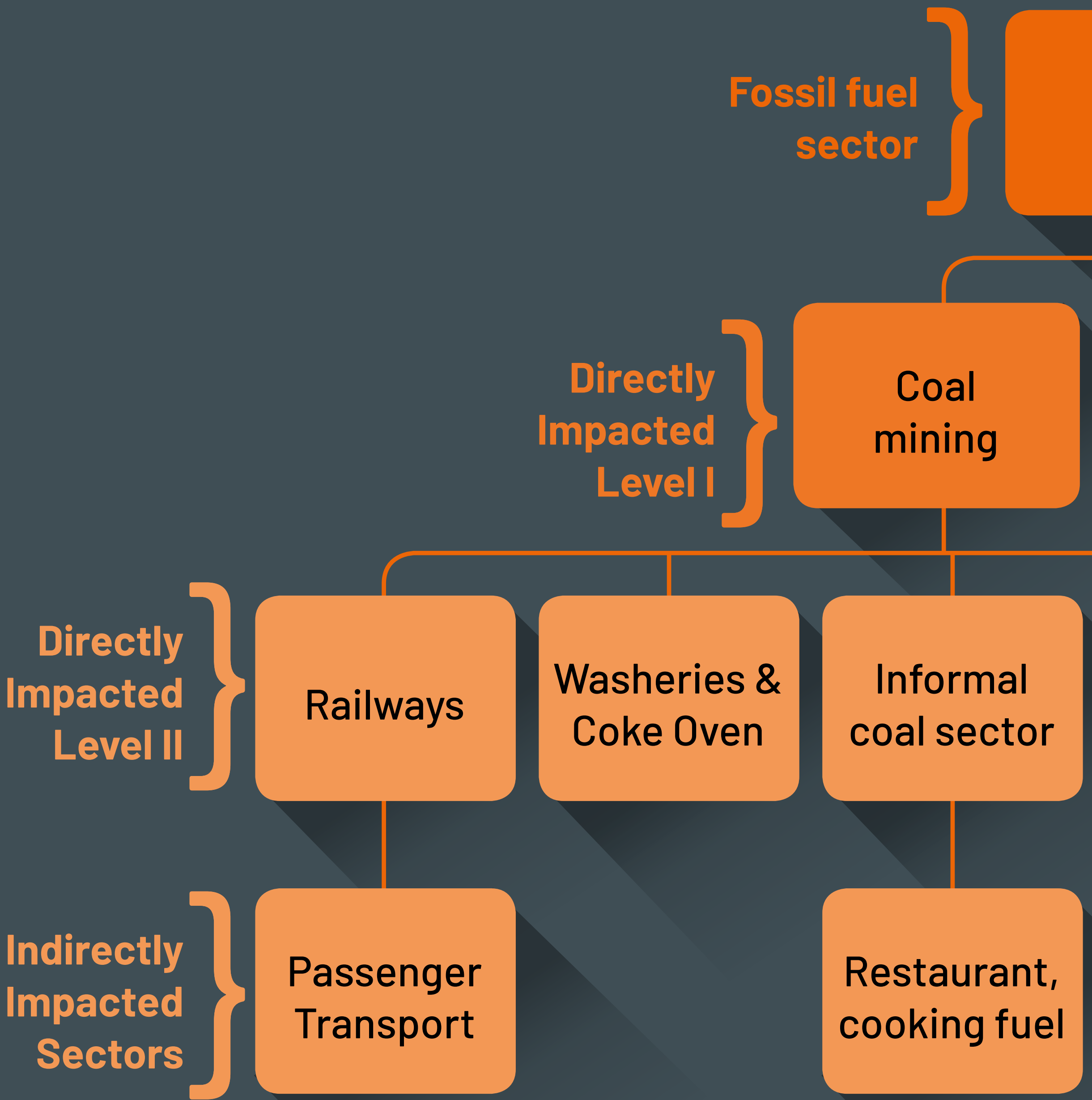
We have analysed the spatial distribution of these sectors, their employment and livelihood dependence, and the development indicators of top fossil fuel districts to assess coping capacity and resilience. Finally, we highlight five critical elements of a just transition, essentially for ensuring a sustainable and just socio-economic transition in our path to net-zero emissions.

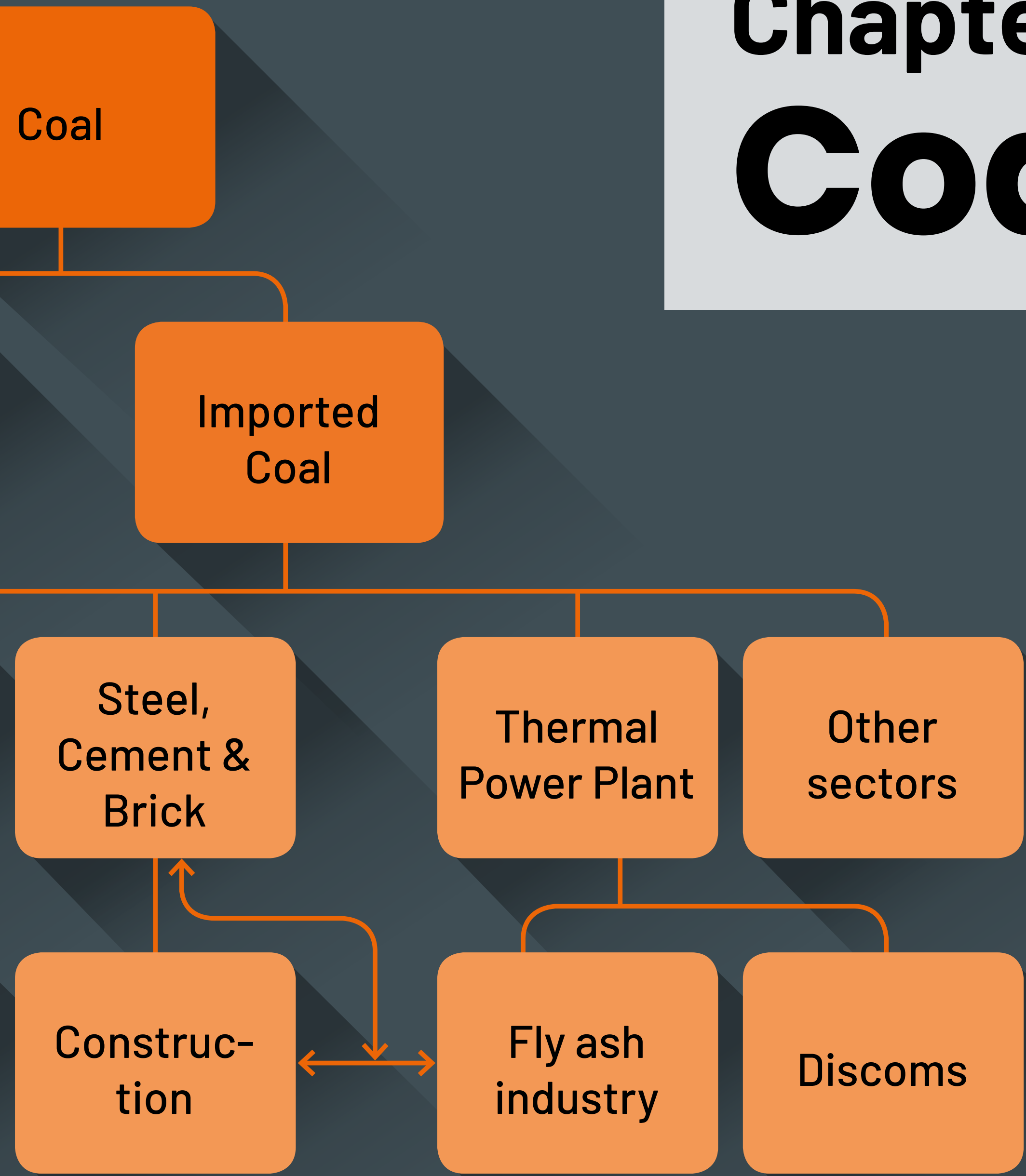
FOSSIL FUELS

Chapter 1
Coal

Chapter 2
Oil

Chapter 3
Natural Gas


Fossil fuel sector
Directly Impacted Level I
Coal mining
Directly Impacted Level II
Railways
Washeries & Coke Oven
Informal coal sector
Indirectly Impacted Sectors
Passenger Transport
Restaurant, cooking fuel



Chapter 1
Coal

Coal is considered the backbone of India's energy supply. Meeting 44% of the country's primary energy demand,[1] it is the single largest source of energy and GHG emissions in the country. The sector is responsible for over 64% of total carbon dioxide (CO_2) emissions from the fossil fuels and cement production.[2] Besides, it contributes to significant emission from other industrial sources that are dependent on coal as fuel, such as steel and brick. Overall, given its centrality in India's energy mix, it has massive direct and indirect impacts on various sectors of economy.

India's coal demand, however, is projected to experience a rapid decline in the next decade due to exponential growth in the renewable energy sector, particularly solar and wind. Moreover, recent studies on India's pathway towards achieving net zero emissions unanimously suggest that coal consumption must reduce drastically, at least to half by 2040.[3]

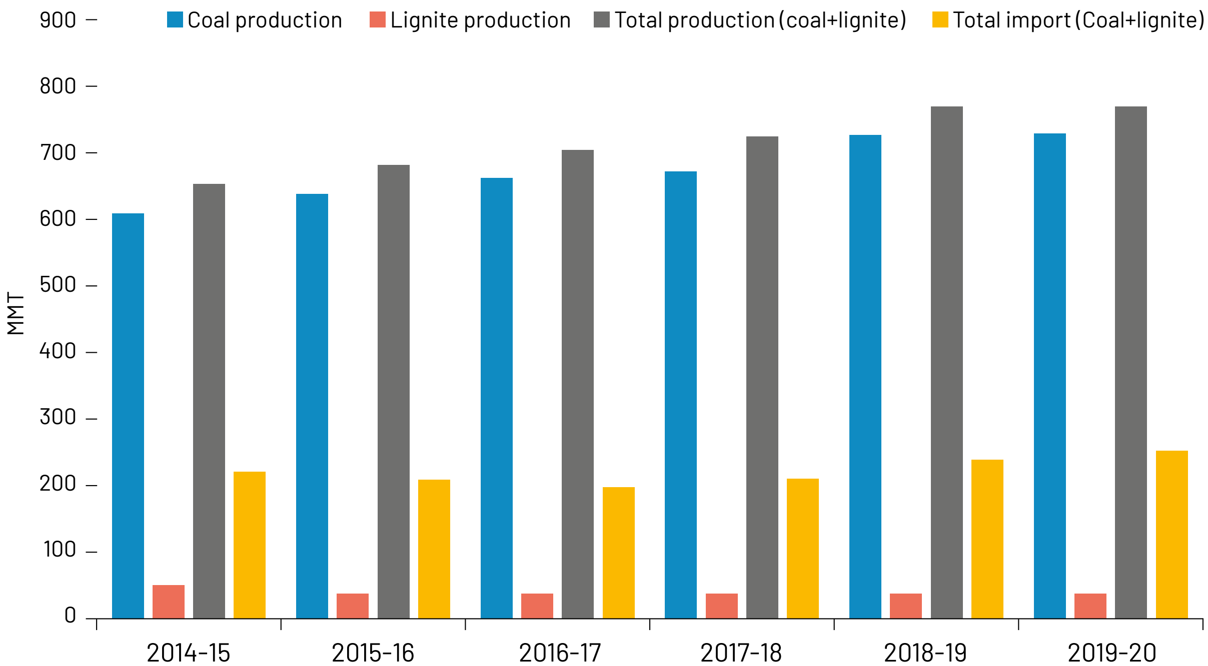
The reduction in coal demand will have a significant impact on coal mining. There are already huge concerns of unprofitability about the low-producing underground mines in various coal districts.[4] Even opencast mines in some areas are experiencing decline in production and 'temporary' closure. For example, in Jharkhand, 50% of the mines are already closed due to unprofitability and other reasons.[5]

Considering the labour distribution in coal mining and related activities (which is dominated by informal workers) and the dependency of several coal regions on this industry,[6] it becomes crucial for the coal sector to conceptualise a road map for just transition in the coming decades.

1. Production and consumption

In 2020, India produced 773 million metric tonnes (MMT) of coal and lignite, of which 95% was by public sector undertakings (PSUs). During the same period, the country imported about 251.5 MMT of coal worth ₹ 1,588 billion (Table 1). Given India's growing energy demand, both coal production and imports have increased over the past five years (Figure 1).

Figure 1: Trend in coal and lignite production and import



Source: Office of the Coal Controller, 2020

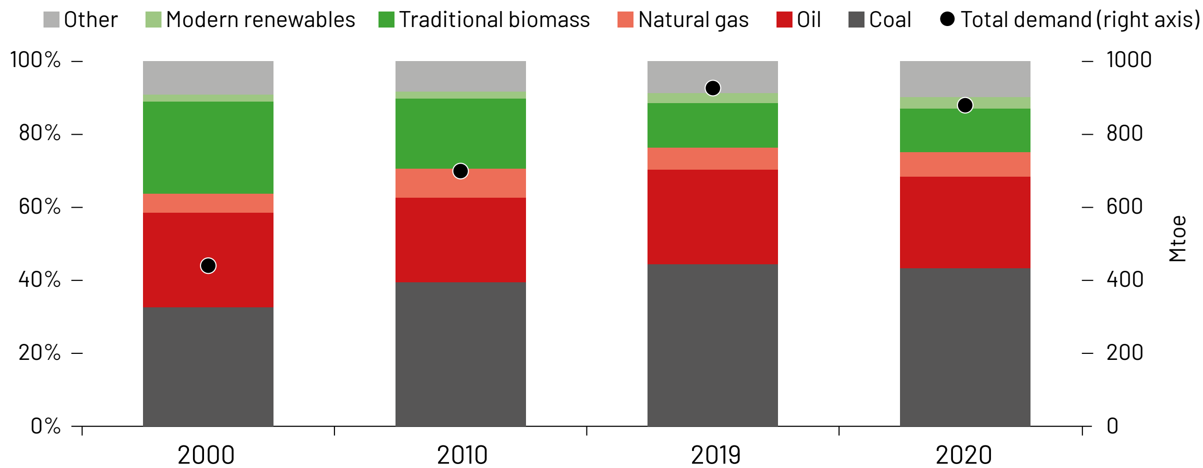
Table 1: Coal and lignite imports (2020)

Type	Import (MMT)	Share of total (%)	Import cost (₹ Billion)
Non-coking	196.7	78.2	914.65
Coking	51.8	20.6	612.67
Coke	2.9	1.2	60.26
Lignite	0.05	0.02	1.07
Total	**251.45**	**100**	**1,589**

Source: Information compiled from NITI Aayog Energy dashboard, 2021

The contribution of coal in India's primary energy demand has steadily increased over the past two decades (Figure 2). This growth in coal's share has been influenced by its demand for power generation and by heavy industries such as cement and steel. Besides, medium- and small-scale industries such as sponge iron and brick are also largely reliant on coal as a fuel source.

Figure 2: Contribution of various sources of energy in primary energy demand



Source: Figure adopted from International Energy Agency, 2021

Power sector remains the single largest coal consumer accounting for nearly three-fourths of the total coal and lignite consumption (Table 2). The demand for coal and lignite has steadily grown in this sector over the past years. For instance, consumption of domestic coal and lignite has increased from 425 MMT in 2010 to 689 MMT in 2019,[7] which suggests a cumulative annual growth rate (CAGR) of almost 5% over the last decade.[8] However, for the first time in 2020, there was a slight dip in coal consumption by the power sector.[9] Though this can arguably be attributed to the COVID-19 crisis, there are clear indications that coal consumption by the power sector will steadily decline in the next decade and thereafter, due to expansion in renewable energy and storage systems.

Among the industrial sectors, the increase in demand for coal has been one of the highest in the iron and steel industry, with a CAGR of about 6.8% in the last decade.[10] The sector is, however, highly dependent on imported (coking) coal, which accounts for about 75% of the coal consumed by the sector.

The cement industry is also highly reliant on coal for clinker production,[11] and is estimated to consume over 40 MMT of coal in 2020. This is going to sharply rise in the coming years, as India's cement demand is expected to reach 550-600 MMT per year by 2025, owing to growing housing and infrastructure demand.[12]

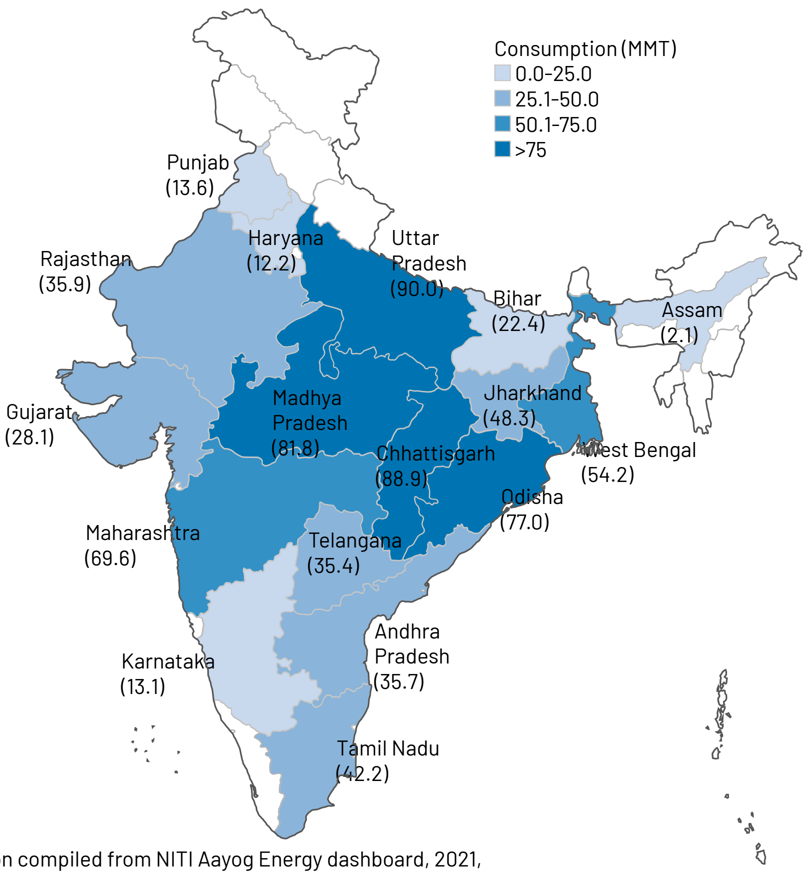
Table 2: Sector-wise coal and lignite consumption (2020)

Sector	Consumption (MMT)			Share of total (%)
	Coal	Lignite	Total	
Power	632.6	36.3	738.1	73.5
Iron & Steel	69.2		69.2	6.9
Cement	40		40	4.0
Brick	35		35	3.5
Sponge Iron[13]	26.4		26.4	2.6
Others	91	4.9	95.9	9.5
Total			**1004.6**	**100**

Source: Estimated by iFOREST
For power and steel sector (including imports), NITI Aayog Energy Dashboard. 2021; For cement sector, calculation is based on IBM, 2020, Indian Minerals Yearbook-Cement and CSIR 2014- specific coal consumption by cement sector; For sponge iron, calculation is based on Annual Report 2019-20, Ministry of Steel and CSIR,2014- specific coal consumption by sponge iron sector; For brick, Bureau of Energy Efficiency, 2019; Figures for other sectors are based on Energy Statistics 2021.

The three top power producing states—Chhattisgarh, Madhya Pradesh, and Uttar Pradesh—had the largest share of coal consumption in 2020, each consuming over 80 MMT of domestic coal. Other key industrial states such as Maharashtra, Odisha, Tamil Nadu, Gujarat, and Rajasthan have significant coal consumption (Map 1).[14]

Map 1: State-wise domestic coal and lignite consumption (2020)

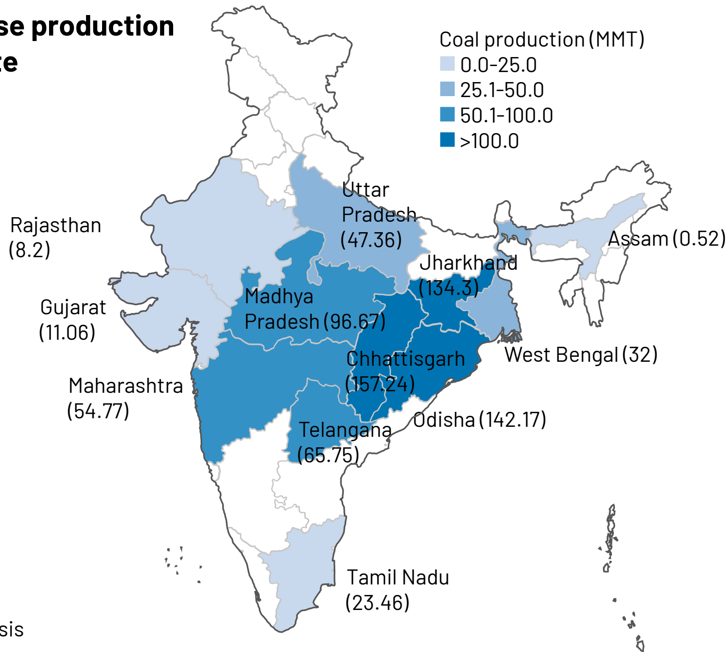


Source: Information compiled from NITI Aayog Energy dashboard, 2021,

2. Spatial distribution

India currently has 459 operational coal mines, combining opencast (OC) and underground (UG) mines,[15] which are mostly concentrated in six states: Chhattisgarh, Odisha, Jharkhand, Madhya Pradesh, Telangana, and Maharashtra (Map 2). In 2019-20, these six states accounted for over 90% of the country's total coal production.

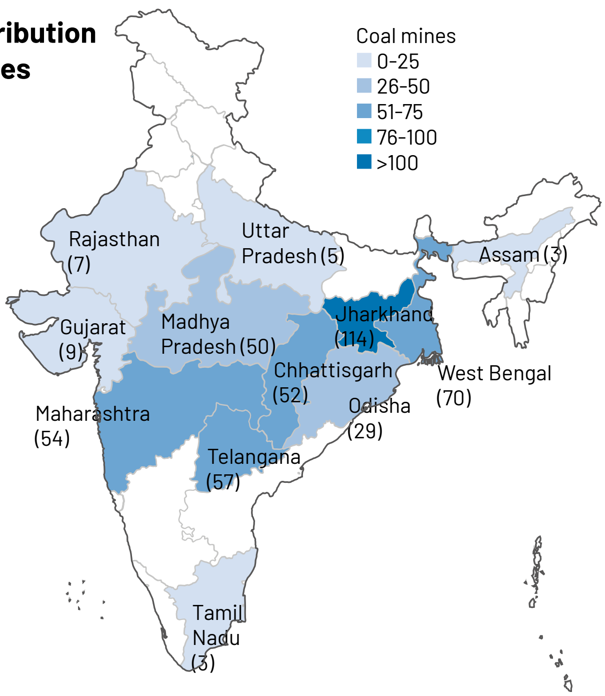
Map 2: State-wise production of coal and lignite



Source: iFOREST analysis

With respect to spatial concentration of mines, Jharkhand tops the chart with 114 coal mines. The other key ones are West Bengal, Telangana, Madhya Pradesh, Maharashtra, and Odisha (Map 3). While Jharkhand has the largest number of mines, in many of the districts, the production capacity is relatively small compared to other major coal-producing states.

Map 3: State-wise distribution of operational coal mines

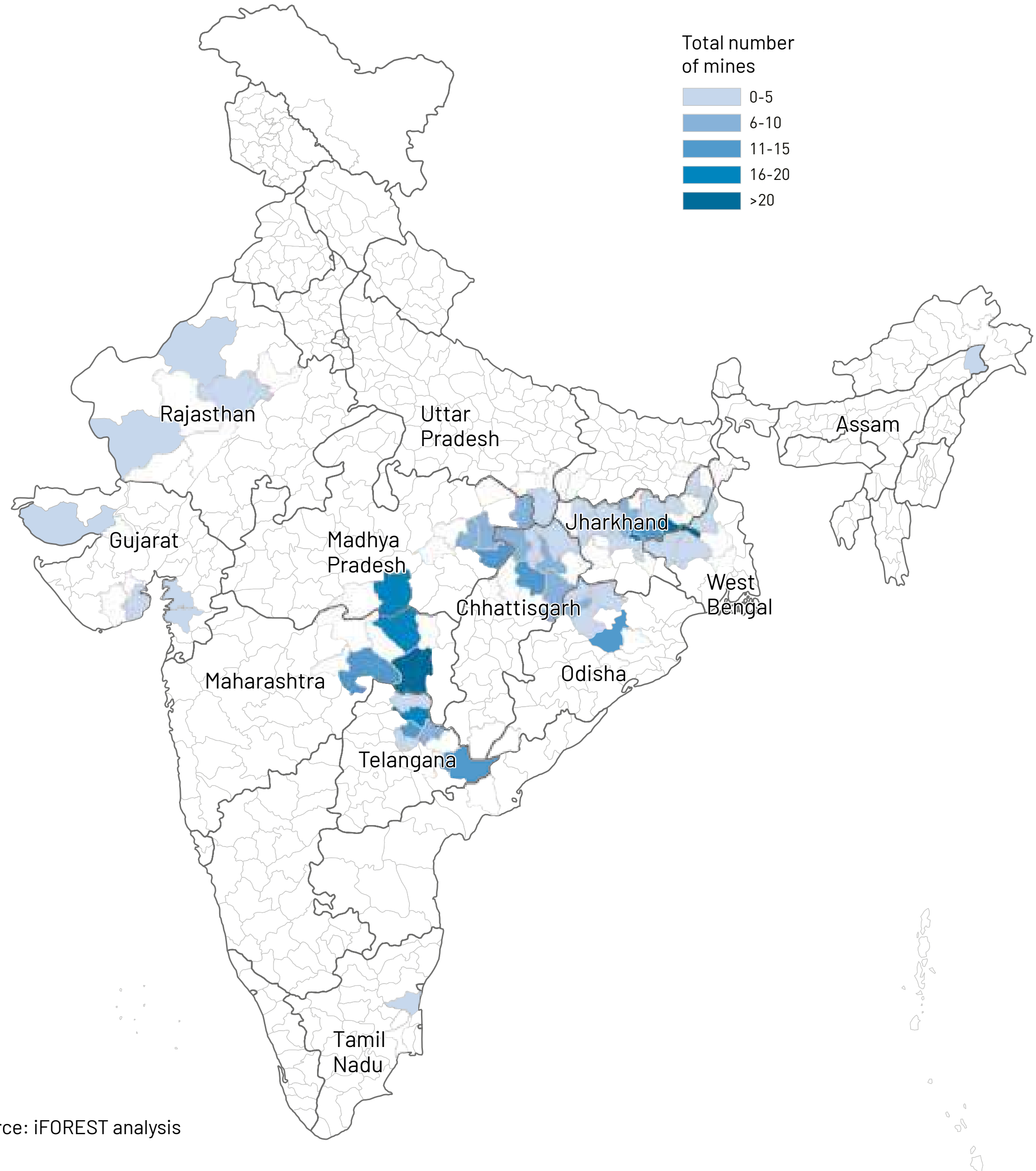


Source: iFOREST analysis

A district-level assessment of coal mines in various states further highlights the highly concentrated nature of mining activities and production in certain parts of India. For example, out of the total 459 operational mines, over 67% (308 mines) are located in just 15 districts (Map 4). The highest number of mines are in Paschim Bardhaman district (West Bengal) with a total of 65 mines (of which 65% are UG). This is followed by Dhanbad district (Jharkhand), with a total of 51 operational mines, of which 33% are UG.[16]

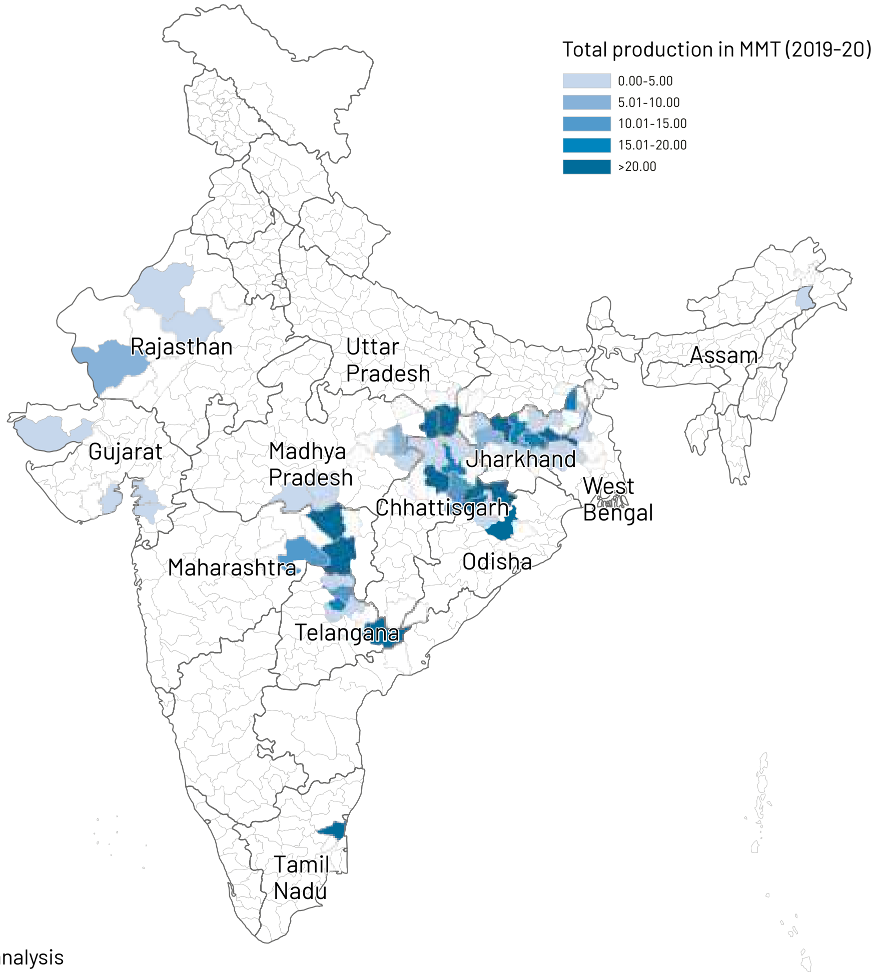
In terms of production, just 25 coal districts account for 94% of India's total coal production (Map 5). Out of these 25, 13 districts produce more than 20 MMT of coal annually, and account for 75% of India's coal and lignite production.

Map 4: District-wise distribution of coal mines



Source: iFOREST analysis

Map 5: District-wise distribution of coal production (MMT)



Source: iFOREST analysis

3. Contribution to the public exchequer

The share of coal and lignite sector to India's GDP is about 0.8%.[17] However, the tax and non-tax revenue from the sector constitute an important income source for the Governments. The Centre's main source of direct revenue from coal are the taxes, duties, and cess, while for the State Governments and Union Territories (UTs), the major source is royalties (Table 3).[18] Districts receive significant contributions to the District Mineral Foundation (DMF) Trust.

Table 3: Central and State/UTs Government revenue from coal (₹ Billion)

Revenue type	2018-19			2019-20		
	Centre	State/UT	Centre+State/UT	Centre	State/UT	Centre+State/UT
Taxes, Duties, Cesses etc.	578.76	44.17	622.93	552.8	46.75	599.55
Royalty, DMFT, State taxes etc.	61.54	172.52	234.06	51.92	169.83	221.75
Total exchequer contribution	744.32	212.09	956.41	604.72	216.58	821.3

Source: Prayas, 2020

3.1 Contribution to Centre and State Government exchequer

Collectively, the contribution of the coal sector to the Centre and the State Governments/UTs' exchequers was over ₹ 956 billion in 2018-19. This showed a slight dip in 2019-20 (₹ 821.3 billion), which can be attributed to the COVID-19 pandemic and associated disruptions.[19] The Government further expects to receive about Rs 66.5 billion (₹ 6656 crore) annually from commercial coal mine auctions that commenced in 2020.[20]

A state-wise analysis gives a clearer picture of the direct revenue dependence of major coal producing states on the sector, as well as the Centre's key sources of coal-based revenue (Table 4).

In most top coal states, the share of direct coal mining revenue (from PSUs, the major operators) in total revenue contribution of the State Governments is 2.5%-5.5% (Table 5).[21] The low revenue share of coal mining can be attributed to the high proportion of UG mines in these states (having low productivity), which contribute little to the royalty or DMF. A classic example is West Bengal, where there is a large number of low-producing UG mines and revenue contribution to the state is one of the lowest.

For the Centre, a major share of revenue, currently, is the Goods and Services Tax (GST) compensation cess (earlier the coal cess). Companies have been paying this to the Centre since 2017 with the enactment of the Goods and Services Tax (Compensation to States) Act 2017.[22] The GST compensation cess as levied at ₹ 400 per tonne on the dispatch of coal and lignite, is one of the largest tax on coal. Thus, the revenue contribution to the Centre exchequer by coal companies is nearly two to three times as compared to the contribution to the State Government exchequer.

Table 4: Contribution of coal mining to Centre and State exchequer in top coal states (2019-20)

State name	Major coal operators considered	Mine operations of companies considered			Coal revenue (₹ Billion)		
		OC	UG	OC/UG	Centre	State	Total
Jharkhand	CCL, BCCL, ECL	66	27	10	61.21	39.92	101.13
Odisha	MCL	17	8		109.64	29.11	138.75
Chhattisgarh	SECL	18	28		90.81	32.21	123.02
Madhya Pradesh	SECL, NCL, WCL	16	35	2	95.54	34.10	129.64
Maharashtra	WCL	39	13		21.29	16.91	38.20
Telangana	SCCL	30	26		0.00	0.00	61.24
West Bengal	ECL, BCCL	13	45	8	14.34	18.35	32.69
Uttar Pradesh	NCL	5			9.19	6.67	15.86
Total							**640.52**

Source: Revenue calculations based on annual reports and accounts of respective coal companies, and NMET and DMF requirements as specified by the Ministry of Mines, 2021

Note: CCL= Central Coalfields Limited; BCCL= Bharat Coking Coal Limited; ECL= Eastern Coalfields Limited; MCL= Mahanadi Coalfields Limited; SECL= South Eastern Coalfields Limited; NCL= Northern Coalfields Limited; WCL= Western Coalfields Limited; SCCL= Singareni Collieries Company Limited

Table 5: Share of coal mining revenue in State revenue			
State name	**Total state revenue (₹ Billion)**	**Revenue from PSU coal companies (₹ Billion)**	**Share of coal in total revenue (%)**
Jharkhand	728.59	39.92	5.5
Odisha	1,117.85	29.11	2.6
Chhattisgarh	756.96	32.21	4.3
Madhya Pradesh	1,485.61	34.10	2.3
Maharashtra	3,098.81	16.91	0.5
West Bengal	1,632.59	18.35	1.1
Uttar Pradesh	3,702.66	6.67	0.2

Source: State revenue calculations Reserve Bank of India, 2020-2021

3.2 District Mineral Foundation funds

The District Mineral Foundation (DMF) funds form a significant share of states' non-tax revenue from coal mining. As per the latest information of the Ministry of Mines (the nodal ministry entrusted with DMF), over Rs 456 billion (₹ 45,977 crore) has accumulated in DMFs of various coal and non-coal mining districts across India. Of the total accrual, the coal's share remains 40.3%, which translates to about ₹ 184 billion.

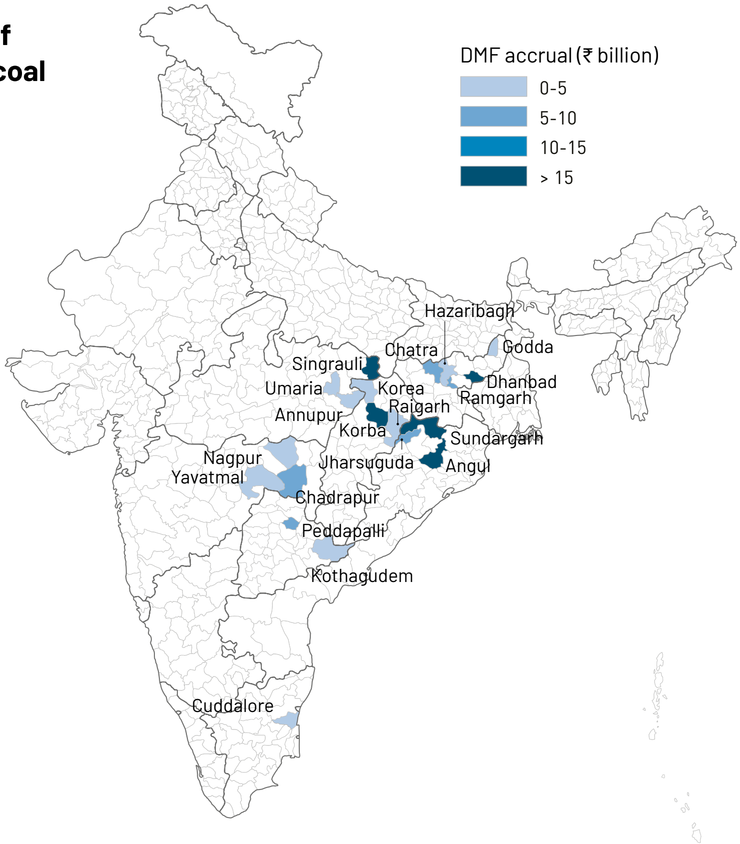
Among the states with the highest DMF share from coal, Jharkhand tops the list. The state's cumulative DMF accrual from coal mining stands at ₹ 47.7 billion (₹ 4,765 crores). Other top coal states also have very significant DMF corpus from coal, such as Chhattisgarh, Madhya Pradesh, Odisha, Telangana and Maharashtra. (Table 6).[23]

Making use of DMF funds to facilitate just transition at the local level is a significant opportunity. The fund is extra budgetary and directly comes to the district as contribution from mining companies. Moreover, the fund is untied and non-lapsable, creating opportunities for short, medium, and long-term investments that are necessary to support a just transition. For instance, the DMF in Dhanbad district—Jharkhand's old coal mining area—has, so far, received ₹ 16.7 billion (₹ 1,670 crore). Similarly, another old coal district, Ramgarh, has ₹ 8 billion (₹ 800 crore) in DMF. In Chhattisgarh's biggest coal district, Korba, the DMF accrual stands at ₹ 17.8 billion (₹ 1,778 crore); in Angul, Odisha's biggest coal mining and power hub, the sum is ₹ 15.6 billion (₹ 1,563 crore) (Map 6).

Table 6: Coal share of DMF in coal producing states			
State name	**Total cumulative DMF accrual (₹ Billion)**	**Coal based accrual (₹ Billion)**	**Share of coal in total (%)**
Jharkhand	65.33	47.65	73
Chhattisgarh	64.7	34.43	53
Madhya Pradesh	37.55	30.4	81
Odisha	121.86	28.97	24
Telangana	29.99	18.98	63
Maharashtra	23.07	14.44	63
Uttar Pradesh	8.9	4.81	54
Tamil Nadu	7.77	3.15	41
Gujarat	8.6	1.09	13
Rajasthan	46.64	0.67	1.4
Assam	0.89	0.52	58
West Bengal	0.66	0.15	23

Source: Information compiled from DMF/PMKKKY dashboard, Ministry of Mines, 2021

Map 6: Distribution of DMF accruals in top coal mining districts



Source: iFOREST analysis

Box 1: Coal and Railways

Besides tax and non-tax revenue, coal mining makes another significant contribution to public revenue in the form of freight revenue to the Indian Railways. A large share of the coal mined in Jharkhand, Odisha, and Chhattisgarh is not used locally (Table 7) and is transported to other states, particularly in northern and western India, for use in various sectors.[24]

Table 7: Coal production vs consumption in key coal states

State name	Production (MMT)	Consumption (MMT)
Chhattisgarh	157.8	88.9
Jharkhand	131.8	48.3
Odisha	143	77.0
Madhya Pradesh	125.7	81.8

Source: Information compiled from NITI Aayog Energy dashboard, 2021

A primary mode of transportation is the railways, and coal accounts for nearly half of all commodity transport of the railways. Every year, the Indian Railways earns about ₹ 544 billion from coal freight, which is nearly half of its total freight revenue earnings (Table 8). This freight revenue generated is used to cross-subsidise passenger fare. Overall, coal and coal-dependent sectors account for over 75% of the freight revenue.[25]

Table 8: Revenue earning from freight traffic of Indian Railways (2019-20)

Commodity/ Commodity group	Sub-commodity	MMT carried	Share of MMT carried (%)	Earnings (₹ Billion)	Share of earnings (%)
Coal	Power houses	252.9			
	Public use	276.8			
	Steel plants	57.1			
	Washeries	0.1			
Total coal		**586.9**	**48.6**	**544.27**	**48.8**
Iron and Steel	Raw material for steel plants except iron ore	25.6			
	Pig iron and finished steel	53.1			
	Iron ore (85.6 MMT for steel plants)	153.4			
Total iron and steel		232.1	19.2	204.69	18.4
Cement		110.1	9.1	87.45	7.8
Fertilizers		51.4		58.08	
Food grains		37.5		61.54	
Mineral oil (POL)		44.7		59.28	
Container services		61.1		25.54	
Balance other goods		84.7		73.89	
Grand Total		1,208.4		1,114.72	

Source: Indian Railways annual reports and accounts 2019-20

However, it is to be noted here that a large volume of coal is also dispatched by modes of road transport such as trucks. While a comprehensive estimation on this is not available, a company-wise estimation of some PSUs for whom data is available shows this. For instance, for three of the major coal PSUs—SECL in Chhattisgarh and Madhya Pradesh, CCL in Jharkhand, and MCL in Odisha—coal is primarily transported through roadways. In fact, for SECL offtake, more coal is transported by road than rail (Table 9).

This trend suggests that in the event of a coal sector transition, it is not only the Indian Railways freight revenue substitution that needs to be considered, but the earnings of the truck freight must also be factored in. From a job and livelihood perspective, road transport is likely to have larger implications than rail transport. Any data on the number of jobs (and estimation of job losses from coal transition), therefore, should account for this.

Table 9: Modes of coal dispatch

Company	Total offtake (MMT) 2019-20	Dispatch mode (MMT)					
		Rail	Road	Merry-go-round	Belt	Consumer's own wagon	Local transport and colliery use
SECL	141.9	49.6	59.5	24.4	6.3	2.1	
CCL	67.3	35.7	22.9				8.8
MCL	134	76.8	43.2	12.4	1.5		0.002

Source: SECL and CCL annual reports and accounts 2019-20, MCL Offtake and transport obtained from company website, 2021 (https://www.mahanadicoal.in/About/eofftake.php)

4. Employment

Employment and livelihood dependence in the coal mining sector is difficult to estimate owing to the association of a large proportion of contracted workers (with no specific information of employment from these contractors) and informal workforce with the sector. For this study, an approximate figure of 'direct' employment[26] (can also be considered formal employment) has been estimated by considering company-wise employment factors (number of employees per million tonne production) for open cast and underground mining operations.[27]

Going by the employment factor approach, currently there are about 0.75 million people associated with direct coal mining jobs provided through parent companies or by contractors running the mines (Table 10).[28] The analysis also shows that UG mining operations employ a disproportionately high number of people compared to their production.

Table 10: Estimated direct employment in operational coal mines

Mine type	No. of mines	Production (MMT/annum)*	Direct employment
OC	256	721.0	531,893
UG	183	36.0	143,377
OC+UG	20	16.4	69,989
Total	**459**	**773.5**	**745,259**

Source: Data adopted from Pai, Zerriffi and Kaluarachchi, 2021; analysis by iFOREST

*Production as per the latest estimates obtained district-wise and can reflect slight departure from Coal Controller and Coal Ministry annual report figures.

The distribution of people directly employed in coal mining is high in top producing states and districts. For example, Jharkhand's Dhanbad district and Chhattisgarh's Korba district have about 0.1 million people each directly employed in coal mining activities. Most of the top coal districts in the states of Jharkhand, Chhattisgarh, Odisha, and Telangana have more than 20,000 people directly employed in coal mining (Map 7).

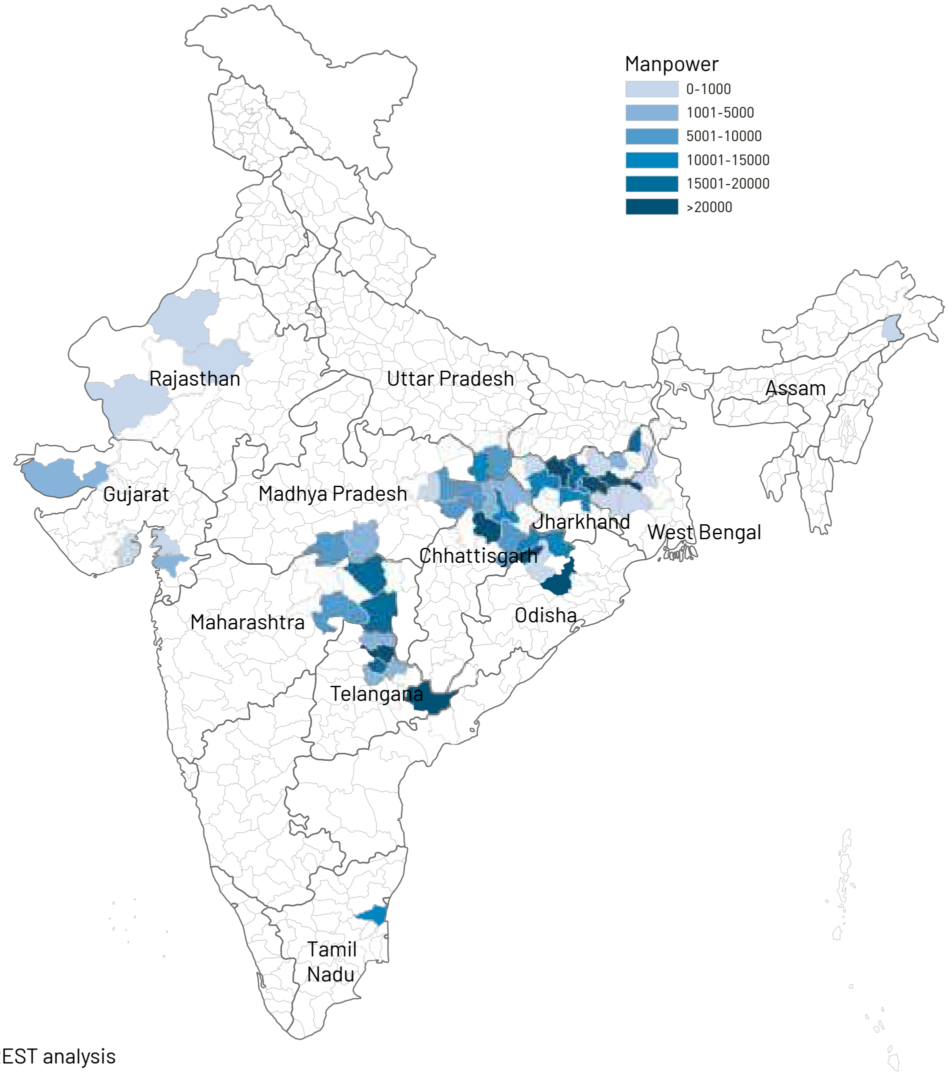
However, a key determining factor in the employment scenario is the type of mining operations in the districts. Typically, districts with a high number of UG mines (even with very low production) have high numbers of people directly employed in mining activities. A classic example of this is Paschim Bardhaman district of West Bengal, which has the highest number of UG mines (42) and is among the top three districts in terms of direct employment (over 68,350 people). A sharp contrast to this is Singrauli district of Madhya Pradesh. Its production volume is one of the highest in the country (more than 82 MMT in 2019-20 from seven opencast mines), but has just over 12,000 people directly employed.

In fact, high direct employment in Dhanbad is also attributed to the high proportion of UG mines (out of 51 operational mines, only 24 are OC, rest 17 are UG and 10 are mixed operations of UG and OC).

However, the main challenge with the coal industry is the vast number of informal workers, who are non-inventoried and are engaged in various activities through a complex set of informal hiring mechanisms such as daily wage by contractors and subcontractors, seasonal wages, part of a group that is referred to as gang, etc. This includes people such as loaders, levellers, carriers, coal transporters, etc.

For an overall estimation of informal workers in the coal mining sector, the 68th round of National Sample Survey (NSS) on employment and unemployment situation of India has been considered. Analysis based on the 68th round data suggests that the mining sector (both coal and non-coal minerals) has nearly 71% informal workers and 29% formal workers.[29] Going by the overall estimate, the number of informal workers is about 1.84 million (however, coal mining will have a higher percentage of informal workers as compared to non-coal mining due to the type of activities involved). Also, the estimates do not account for a large number of people in mining areas who are dependent on coal for subsistence livelihood by gathering and selling coal in local markets. This is a typical phenomenon in old coal regions of eastern India such as Jharkhand and West Bengal.[30]

Map 7: Distribution of formal coal mine workers



Source: iFOREST analysis

5. Future trend of coal sector

While the coal mining sector has been experiencing an overall production growth, there are two factors that suggest a declining demand in coal mining activities as well as the closure of coal mines in coming years. These include:

i. Reduction in demand for coal by power sector; and

ii. Unprofitability of low-producing underground mines.

i. Reduction in demand for coal by power sector: The demand of coal is estimated to go down in the coming decades, particularly considering its diminishing share in power generation, given the advancement in renewable energy (RE) technologies and the share of electricity generation from non-conventional sources.

The Central Electricity Authority (CEA) has projected a significant reduction in coal-based power installation and generation capacity over the next 10 years. By 2029-30, the percentage share of RE in the total installed capacity is projected to be nearly twice of coal and lignite-based sources (Table 11). The CEA has also projected an increase in the share of RE in gross electricity generation. While RE's share in total installed capacity is currently about 21%, its share in gross generation remains only about 9%. This is due to several reasons, including grid capacity, issues with storage systems, etc. By 2029-30, the share of RE (combining solar, wind, hydro, and biomass) in gross electricity generation has been estimated to be 44% (factoring in the reduction in price of battery energy storage systems).[31]

Table 11: Estimated installed capacity by 2029-30

Energy resources	Capacity (MW)	Share of total (%)
Coal and Lignite	266,827	32.1
Gas	24,350	2.9
Nuclear	16,880	2.0
Solar	300,000	36.1
Wind	140,000	16.8
Biomass	10,000	1.2
Hydro	73,445	8.8
Total	831,502	
Battery energy storage	34,000MW/136,000MWh	

Source: Central Electricity Authority, 2020

While there can be some revisions in the timeframe of this estimates due to the impacts of COVID-19 pandemic, yet there remains high optimism about the exponential growth in solar power in the coming two decades and consequent reduction in coal's share in power generation.[32]

The International Energy Agency (IEA), in 2021, has come up with revised projections for India's fossil fuel sector and energy outlook in the next two decades (by 2040). The projections have been done based on three scenarios: the Stated Policies Scenario (STEPS), the India Vision Case (IVC), and the Sustainable Development Scenario (SDS).[33]

Under all the three scenarios, from the most conservative STEPS to the most ambitious SDS, electricity from coal shows a steady decline in the next 20 years. In 2019, while the share of coal-based electricity is nearly 57%, it is projected to decline to 34% in 2040 under STEPS, to 25% under IVC, and to 5% under SDS scenario (Table 12).

With respect to coal production and supply, while there is no decline in STEPS and IVC scenarios, there is a rapid decline in SDS (Table 13).

Table 12: Electricity generation under STEPS, IVC and SDS

Indicator	Current	STEPS		IVC		SDS	
	2019	2030	2040	2030	2040	2030	2040
Electricity generation (TWh)	1,583	2,461	3,887	2,599	4,225	2,365	3,601
Coal	1,135	1,343	1,334	1,099	1,076	708	181
Solar PV	48	392	1,221	517	1,307	584	1,368
Wind	66	195	520	251	677	343	782
Hydro	175	226	307	226	307	258	361
Other RE	42	81	121	81	121	118	320
Total renewables	332	893	2,169	1,074	2,413	1,302	2,832
Natural gas	71	108	157	309	509	240	337
Nuclear	40	109	222	109	222	107	247

Source: International Energy Agency, 2021

Overall, it can be concluded that India's coal mining sector is likely to experience a rapid downsizing over the next two to three decades to meet the climate goals. This has huge implications for the major coal producing districts (Box 2: Just transition in coal districts).

ii. Unprofitability of low-producing underground mines: There are a large number of low- producing UG mines, particularly in India's old coal mining regions such as Jharia and Raniganj coalfields in Jharkhand and West Bengal, respectively. There are 183 operational UG mines (out of total 459 operational mines), which account for only 36 MMT of domestic coal production. Similarly, labour productivity of these mines is extremely poor. Over 0.14 million people (direct and contractual) are employed by these mines. Continuing with many of them has become a liability for the coal companies.

In 2017, Coal India Limited (CIL), India's largest coal producer, had identified 65 loss-making mines for closure, out of which 62 were UG operations. These mines employed about 40,000 workers at that time, which was about 13% of the company's total employee strength.[34]

The burden of UG mines continues to grow on CIL and its subsidiaries. While less than 5% of the company's raw coal production comes from these mines, they account for about 40%-45% of CIL's total workforce. The company nearly incurs a loss of about ₹ 160 billion (₹ 16,000 crore) annually from continuing with these operations, which is about the same as the company's annual profits (₹ 167 billion) in 2019-20.[35] In fact, the company, in its latest annual report (2019-20), has identified "high cost of production in underground (legacy) mines" as coal companies' top "weakness".[36] There is merit in closing down underground mines and using the extra profits of coal companies to start just transition in coal regions.

Key players of the coal industry are wary of the transition that the sector will undergo in the coming years, considering rapidly changing market demands as well as opportunity for investments in other sectors such as RE and extraction of non-coal minerals.[37]

In 2018, CIL announced a target of 20 gigawatt (GW) solar power generation in the next 10 years as part of the company's diversification plan.[38] Recently, in April 2021, the company further announced the establishment of two wholly-owned subsidiaries—CIL Solar PV and CIL Navikarniya Urja Limited—for undertaking solar photovoltaic manufacturing and renewable energy projects.[39]

Box 2: Just Transition in coal districts

More than 90% of the workforce in India are linked to the informal economy, comprising people who belong to socially and economically backward sections of the society.[40] Coal mining sector is no exception to this.

Formal employment in coal (and lignite) mining operations, which is about 0.75 million, reflects a fraction of the overall income dependence on the coal industry.[41] Apart from the fact that official estimates of informal workers directly related to coal mining activities is nearly 2.5 times the formal workers, there is a huge section of people in India's old coal mining areas for whom coal is a subsistence resource. In the coal-bearing areas of Eastern India, which spans across Raniganj coalfields of West Bengal to Jharia and North Karanpura coalfields of Jharkhand, there are millions of people who earn a living by gathering coal manually and selling in local markets.[42] These people, commonly referred to as '*cycle wallahs*', are a common sight in top coal mining districts of Jharkhand, including Dhanbad, Hazaribagh, Ramgarh, and Chatra. An empirical study in Ramgarh district of Jharkhand—where one in four households depends on coal for an income—shows that gathering and selling coal is the primary source of income for about two-thirds of the coal-dependent population.[43]

The informal and unorganised workforce also do not have any bargaining power, which is a major challenge. Though there are several labour laws to protect them such as the Unorganised Workers Social Security Act (2008) and the Minimum Wages Act (1948), including state-specific rules, these are barely exercised. The desperation of 'some income' sustains an ecosystem of exploitation (by various middlemen), and labour rights take a backseat.

Not only there is a large proportion of informal workforce with low income (and no social security benefits) in the coal mining regions, but these regions are also saddled with poor social infrastructure and development indicators. In several top coal mining districts of India, more than 40% of people are multi-dimensionally poor, which is much higher than India average of 27.5%. Hence, these people have lower adaptive capacity for any abrupt and unplanned closure of mining activities.[44]

Therefore, just transition in coal districts of India will have to be beyond just a transition of the formal workforce and consideration for creating decent jobs for them. Predominance of informal workers (and subsistence economy), along with poor human development indicators, will require envisioning and planning a broad-based socio-economic transition to ensure justice for all.

As the first step, the process of a just transition must engage with the informal sector. A bottom-up approach will be necessary to capture the needs and aspirations of these people, including identifying their skills, potential for adapting to alternate livelihood opportunities, and scope of mobility. Moreover, considering the significant presence of marginalised communities in many of the coal mining regions and engagement of a large number of women in various informal work arrangements (and also subsistence work such as gathering coal), the just transition process must take into account issues of gender and vulnerabilities of marginalised communities, alongside the informal workers.

Secondly, as most of the people working in the informal sector are semi-skilled and unskilled, the economic diversification plans must be broad-based to secure alternative livelihood opportunities for this category. This may include:

- Expanding livelihoods in natural resource-based sectors such as agriculture, forestry, fisheries, etc;
- Augmenting Government employment generation schemes;
- Employment in building new social and economic infrastructure; and,
- Skill development to join the formal economy.

Finally, as the fossil fuel-dominant regions have comparatively poor Human Development Indicators and physical infrastructure, there is a need to strengthen social and physical infrastructure and safety nets to secure long-term welfare gains and build community resilience to adapt to a transition.

6. Transition roadmap

The coal sector is ripe for a transition considering the availability of affordable alternative technologies to replace coal use in many sectors, most importantly the power sector. However, there are both challenges and opportunities in ensuring a just transition.

- There is a strategic need to prioritise and start planning just transition in India's old coal belts such as in West Bengal and Jharkhand, which have a large number of old UG mines. Low-producing and loss-making UG mines are a drag on a company's balance sheet. This creates a situation where these mines can be closed temporarily or permanently without any planning. The unplanned mine closure must be avoided.
- Closing down unprofitable mines and using extra profit to start the process of just transition is a win-win opportunity for coal companies, workers, and communities.
- There are other resources that can be utilised for just transition:
  - » One of the biggest revenue sources that can be made available is the GST compensation cess. Post 2022, this cess should be reinstated as the coal cess, or as a clean energy transition cess, and can be used to support just transition and achieve gainful outcomes.

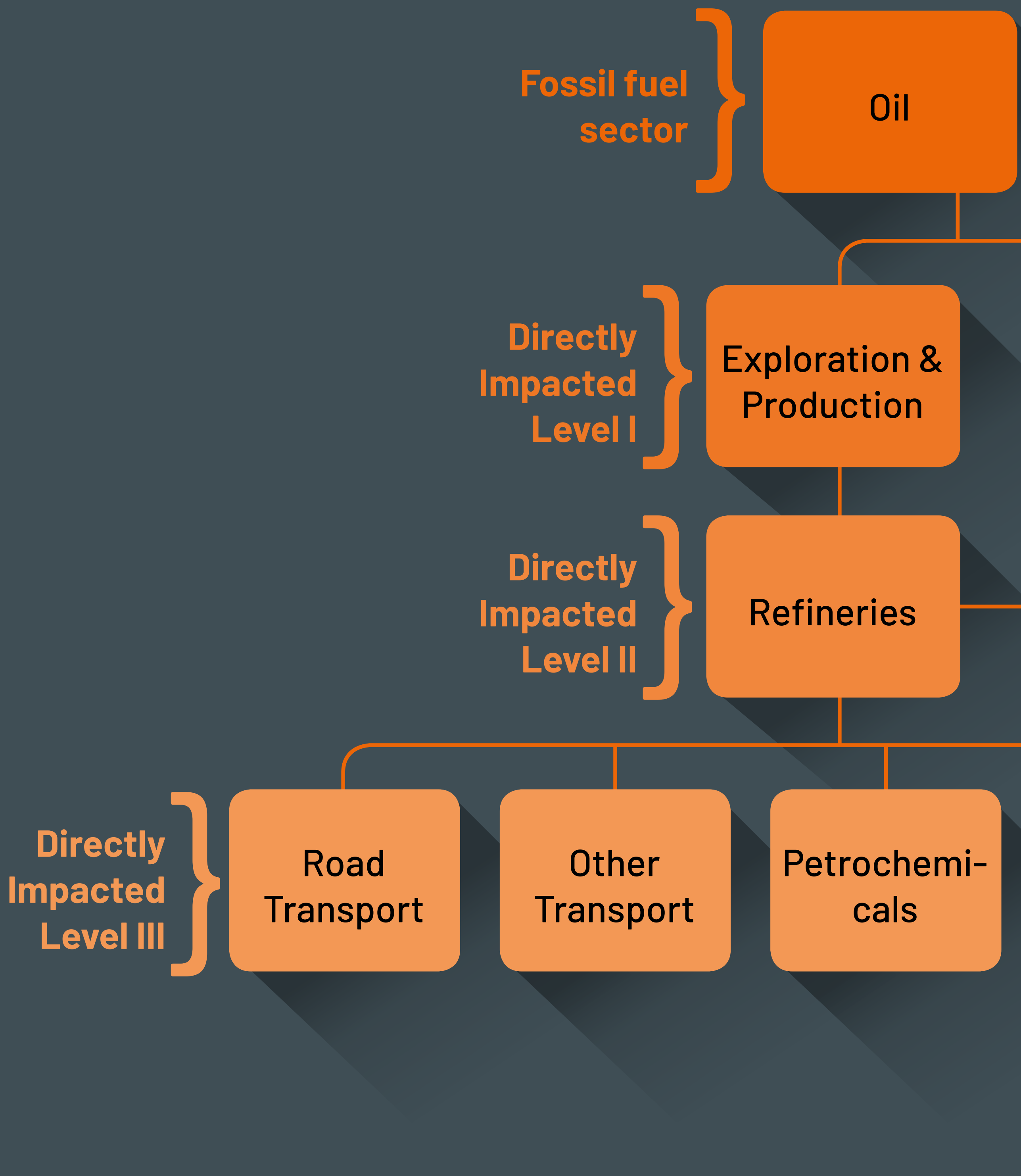
» The other key revenue source from coal that creates significant opportunity for supporting just transition at local levels is the DMF funds. Currently, this significant corpus is being misutilised or underutilised in almost all top coal producing states. A proper planning mechanism for using DMF funds with the objective of just transition will ensure that the funds' potential is harnessed optimally.

» The perception of huge revenue loss due to decline in coal mining is not as grave as it is considered. The GST for coal mining is lower than many other industrial sectors.[45] In fact, in most of the top coal mining states, the share of revenue from coal mining is below 5% of the state revenue.

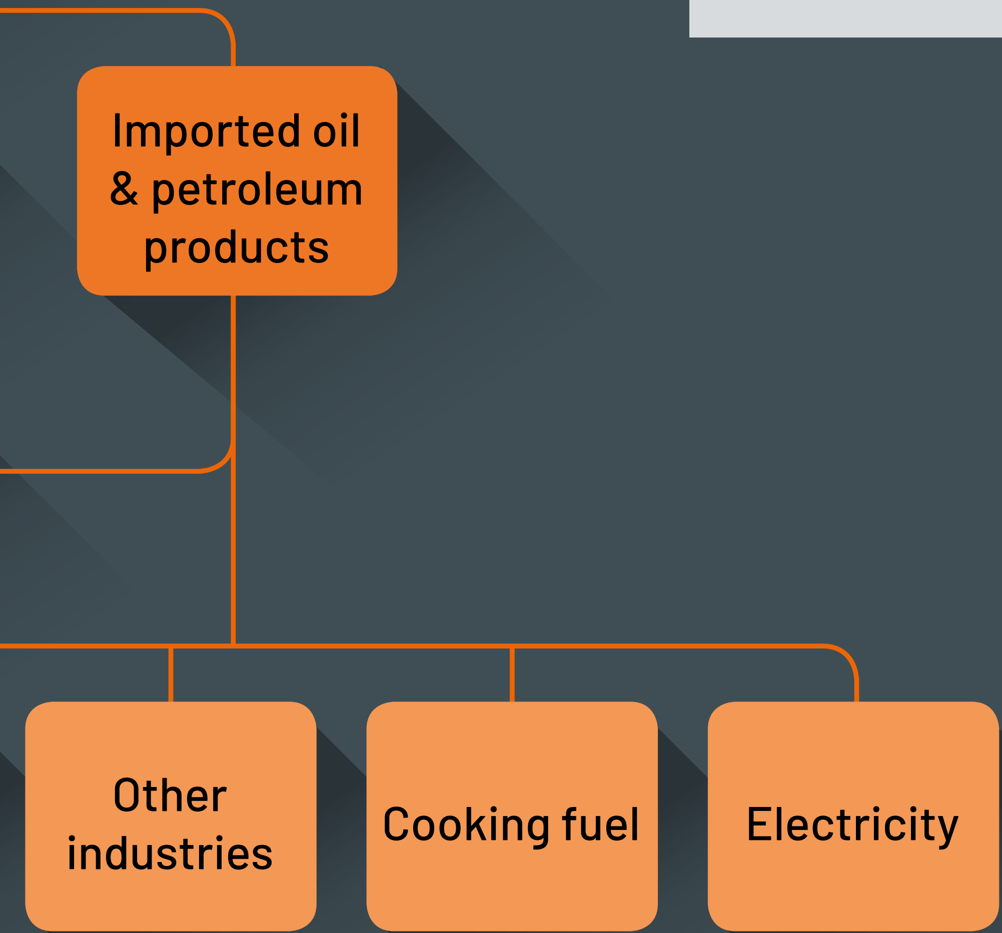
For the above to happen, the Government will need to develop a policy aligned with its energy transition targets and climate commitments. A national level policy needs to be developed in the immediate future to prevent haphazard closure of mines and socio-economic disruptions. The policy should include components of-

- Coal phase-out strategy at the national and state-level (based on a mapping exercise);
- Coal-based power phase out plan, and simultaneous incentivisation of clean energy;
- Regulatory revisions of the coal industry pertaining to mine closure and reclamation, leasing/lease transfer, labour, etc.

Also, it will be crucial to reduce coal requirements for various downstream sectors/industries that are reliant on it. The transition scenario of these industries is discussed in the following sections.


Fossil fuel sector
Oil
Directly Impacted Level I
Exploration & Production
Directly Impacted Level II
Refineries
Directly Impacted Level III
Road Transport
Other Transport
Petrochemi-cals

Chapter 2
Oil



The oil sector is already facing transition challenges due to shift in some of the end-use sectors that have historically relied heavily on petroleum products. Road transportation sector is key among them. As electrification of fleet has become a major tool to reduce local pollution and GHG emissions, the popularity of electric vehicles (EVs), particularly cars, two-wheelers and three-wheelers (2Ws and 3Ws), is growing. Backed by policies, industry investments and consumer demand, it is projected that by 2030, EV sales will constitute 60% of the total car sales globally, up from mere 5% today.[1] While, it is true that any decline in oil demand due to penetration of EVs could be offset by demand growth in other sectors such as freight transport or petrochemicals (which currently have fewer and more costly substitutes),[2] yet transition in certain sectors of the oil value chain in the coming years is inevitable.

For India, the demand for oil has increased rapidly over the last decades and it is now the third-largest oil-consuming country in the world.[3] Today, oil has a share of over 26% in the country's total primary energy supply, making it the second largest after coal.[4] However, oil demand, is projected to reduce in some of the end-use sectors such as transportation and domestic use. While the projected rise in EV sales of India over the next two decades[5] will have major implications for petrol demand, the penetration of liquefied petroleum gas (LPG) as a cooking fuel has already resulted in a steady decline of kerosene consumption (declining at CAGR of 12% over the last decade). Now, piped natural gas supply and electricity (for cooking) are poised to reduce LPG demand, particularly in the cities.

From a just transition perspective, the downstream sector of the oil industry is of the highest significance to India. This includes refining and production of petroleum products, and their marketing and distribution. The upstream sector, which includes exploration and production of oil, is not significant as India is heavily reliant on import of crude oil, which has remained 82% - 85% in the past years. In 2019-20, domestic oil production stood at 32.2 million metric tonnes (MMT), while 226.9 MMT was imported. In fact, over the past 10 years, there has been a steady decrease in domestic production, while imports have gone up.[6] Therefore, even if India continues to produce oil at the current levels, it can easily meet its decarbonisation targets of 2050.

1. Refineries

There are 23 refineries in India (18 public sector, 3 private sector and 2 joint venture), with a cumulative production capacity of about 250 million metric tonnes per year (MMTPA). They are located in 22 districts across 18 states (Table 1).

Among the public sector companies, the largest player is the Indian Oil Corporation Limited (IOCL) with nearly 28% of total refining capacity in the country. The major private player is the Reliance Industries Limited (RIL) with over 27% refining capacity.

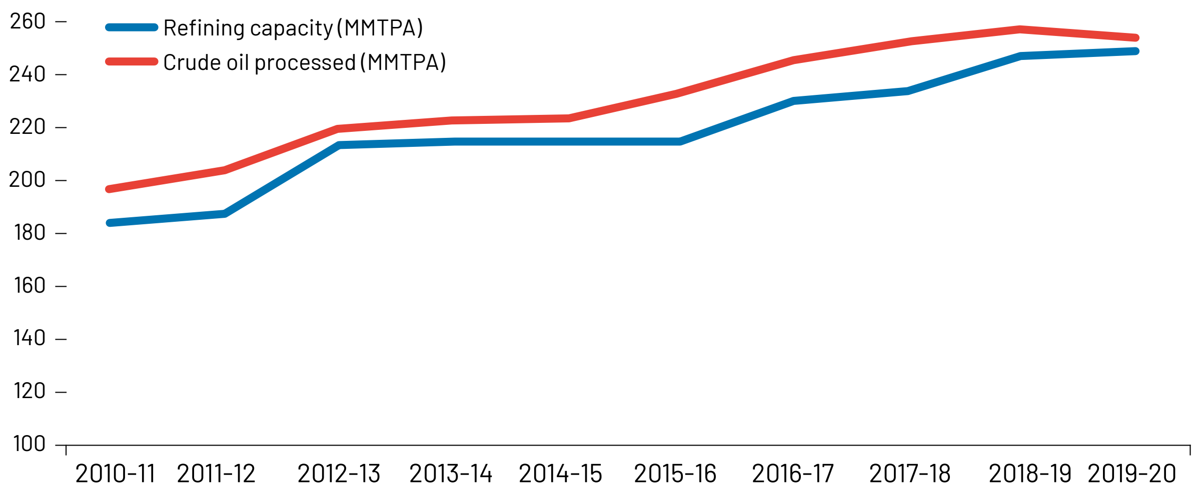
The refining capacity in the country has grown at a compound annual growth rate (CAGR) of 3.5% over the last decade (2010-11 to 2019-20). The growth in crude oil output from the refineries has also increased at a CAGR of 2.9% during the same period. This has aided India to become the fourth largest refiner in the world, and the second largest in Asia (after China).[7]

Table 1: Distribution of oil refineries

State	District	Company	Year of commissioning	Capacity (MMTPA)
Assam	Digboi	IOCL	1901	0.65
Assam	Guwahati	IOCL	1962	1
Assam	Bongaigaon	IOCL	1974	2.35
Bihar	Barauni	IOCL	1964	6
Gujarat	Koyali	IOCL	1965	13.7
West Bengal	Haldia	IOCL	1975	8
Uttar Pradesh	Mathura	IOCL	1982	8
Haryana	Panipat	IOCL	1998	15
Odisha	Paradip	IOCL	2016	15
Maharashtra	Mumbai	BPCL	1955	12
Kerala	Kochi	BPCL	1963	15.5
Maharashtra	Mumbai	HPCL	1954	7.5
Andhra Pradesh	Visakhapatnam	HPCL	1957	8.3
Tamil Nadu	Manali	CPCL	1965	10.5
Tamil Nadu	Narimanam	CPCL	1993	1
Assam	Numaligarh	NRL	1999	3
Andhra Pradesh	Tatipaka	ONGC	2001	0.07
Karnataka	Mangalore	MRPL	1996	15
Gujarat	Jamnagar	RIL	1999	33
Gujarat	Jamnagar	RIL	2008	35.2
Gujarat	Vadinar	Nayara Energy Limited	2006	20
Madhya Pradesh	Bina	Bharat-Oman Refinery Limited (BORL)	2011	7.8
Punjab	Bhatinda	HPCL-Mittal Energy Limited (HMEL)	2012	11.3
Total				**249.9**

Source: Ministry of Petroleum and Natural Gas, 2021

Figure 1: Trend in refinery capacity and processing



Source: Data adopted from Ministry of Petroleum and Natural Gas, 2021

1.1. Production

The highest proportion of petroleum products produced domestically include diesel and petrol, which are consumed by the transportation sector. In 2019-20, high-speed diesel oil (HSD) accounted for 42.3% of the total output, followed by petrol (motor gasoline), which accounted for 14.7%.[8] India is also a net exporter of these products (Table 2).

With respect to LPG, which is another highly consumed product, India's current imports exceed its domestic production. The other major imported product is petroleum coke, which is primarily used in the industries, especially as feedstock in coke ovens for the steel industry and as a substitute for coal in cement industry.[9]

Table 2: Production and availability of petroleum products

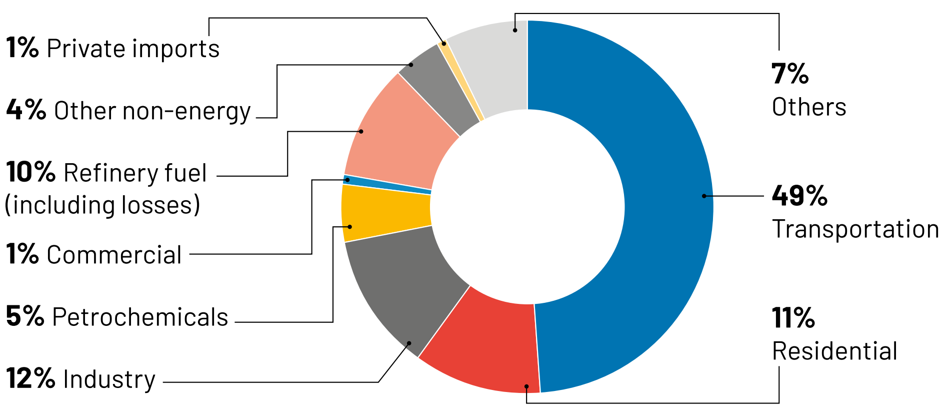
Product	Production (MMT)	Import (MMT)	Export (MMT)	Availability (MMT)
Diesel (HSD+LDO)*	111.8	2.8	31.7	83.0
Petrol (motor gasoline)	38.6	2.2	12.7	28.1
LPG	12.8	14.8	0.5	27.2
ATF	15.2	0.1	6.9	8.4
Kerosene	3.1	0.0	0.2	3.0
Naphtha	20.7	1.7	8.9	13.4
Fuel oil	8.6	4.6	1.5	11.7
Lubes	0.9	2.7	0.0	3.6
Bitumen	5.2	1.6	0.0	6.8
Petroleum coke	15.5	10.7	0.5	25.7
Others	30.3	2.8	2.9	30.2
Total	**262.9**	**43.8**	**65.7**	**241.0**

Source: Ministry of Petroleum and Natural Gas, 2021; *Production of HSD is 111.2 MMT; LDO=Light Diesel Oil

1.2. Demand and replacement technologies

India's oil demand grew by more than 50% over the last decade, mostly led by rapid demand growth in the transport sector and residential consumption—a big driver of which is use of LPG as cooking fuel.[10] In 2019-20, the transport sector accounted for nearly half (49%) of the total oil consumption (Figure 2). The two other major sectors are the residential and industrial sectors, accounting for 10.7% and 11.5% of total consumption, respectively.[11]

Figure 2: Oil consumption by various sectors (%)



Source: Data adopted from NITI Aayog Energy Dashboard, 2021

With respect to end-use consumption of petroleum products by various sectors, the highest consumption is of diesel and petrol by the transport sector through retail (Annexure 3). Diesel remains the most consumed oil product, accounting for 39% of total petroleum product consumption in 2020, primarily used for freight/ commercial transportation. Petrol consumption accounts for nearly 14%, which has grown over the past years, due to increase in the number of passenger cars and 2Ws and 3Ws.[12]

For LPG, which is the most consumed petroleum product after diesel and petrol, the highest demand is for cooking fuel (domestic distribution), accounting for 87.6% of the LPG consumption.

As industrial fuel, the major petroleum products are petroleum coke (largely by the steel industry) and furnace oil. Besides, low-sulphur diesel stock and light diesel oil (LDO) are also used for industrial consumption. Another major petroleum product, naphtha, is primarily consumed by the petrochemical industry.

However, the refining sector faces major challenges because of the significant changes in product demand due to the availability of alternative technologies.

With rapid electrification of cars and 2Ws and 3Ws, there will be a major drop in demand for petrol in the next few years. Similarly, electricity, biofuel and hydrogen will reduce the demand for diesel, but this will take longer as replacement technologies are not yet market-ready. Oil products used as industrial fuels will also be replaced by electricity, bio-fuels or hydrogen over the next 10-15 years as cost-effective heat pumps and other electric-based systems become widely available.

The only sector where demand is likely to increase is petrochemicals. This means that products like naphtha could see an increase in production. But overall, refinery sector will see significant reductions and closures.

2. Marketing and Distribution

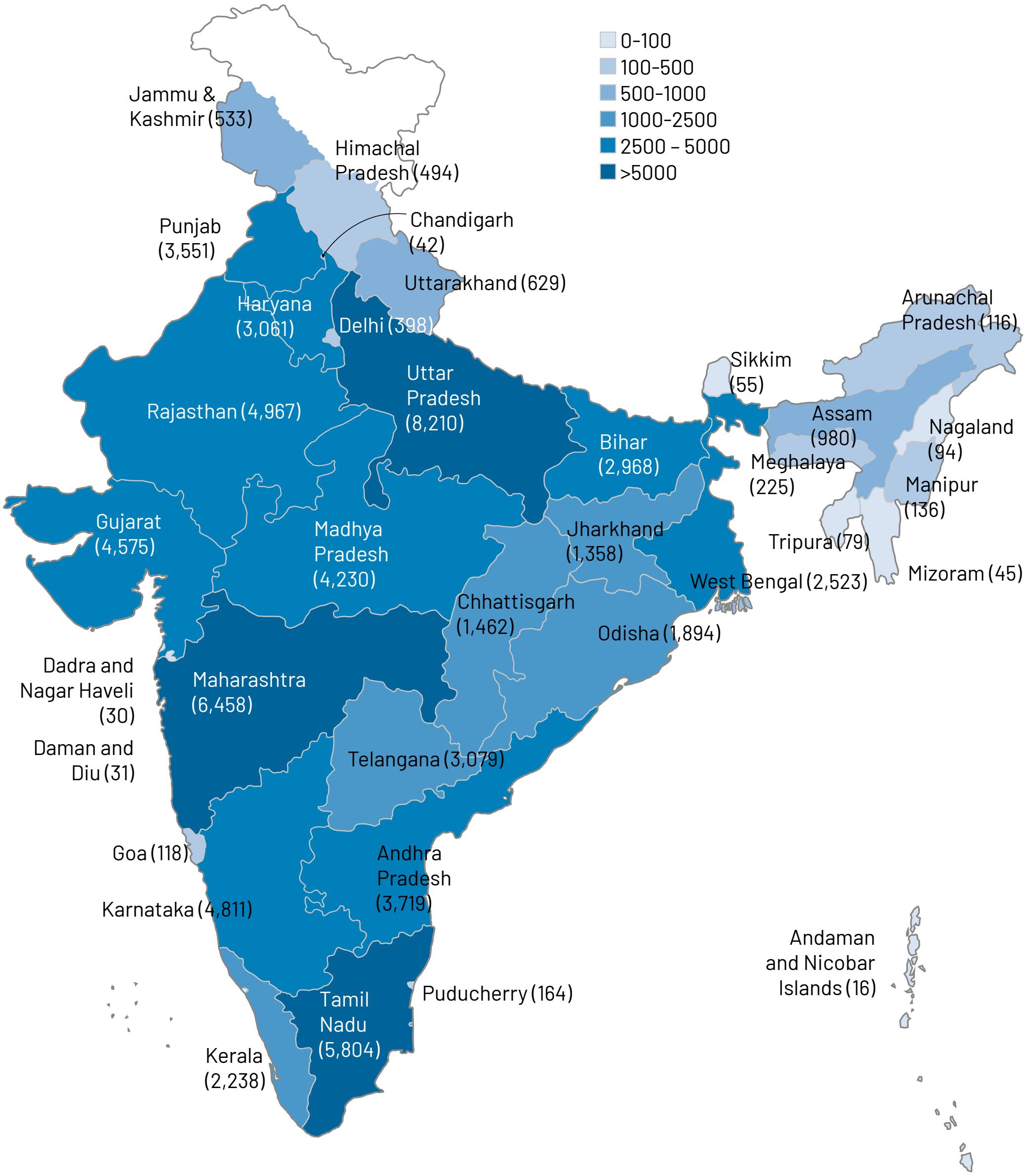
In the oil industry, major marketing and distribution happens for products such as diesel, petrol, and domestic fuel (LPG and kerosene). The marketing and distribution sector is very significant for a just transition because this is where the most immediate impacts of oil transition will be experienced in India. As noted earlier, the triggers such as momentum for EVs and changing patterns in cooking fuel are already there.

The marketing and distribution components are also important from an employment perspective. The formal employment in marketing and distribution is, in fact, far more than the employment provided by the oil and gas companies, including refineries (See section on employment). Besides formal employment, marketing and distribution also employs a large number of semi-skilled and contract workers.

2.1. Retail outlets

India's rising vehicle fleet has contributed to the increasing number of retail outlets/petrol pumps. The number of petrol pumps has increased from 45,104 in 2011-12 to 63,093 in 2019-20.[13] Typically, the number of petrol pumps is correlated with population and urbanisation (Map 1). The Government of India further plans to increase the number of petrol pumps to ensure adequate availability of fuels like petrol and diesel.[14]

Map 1: State-wise number of petrol pumps (2019-20)



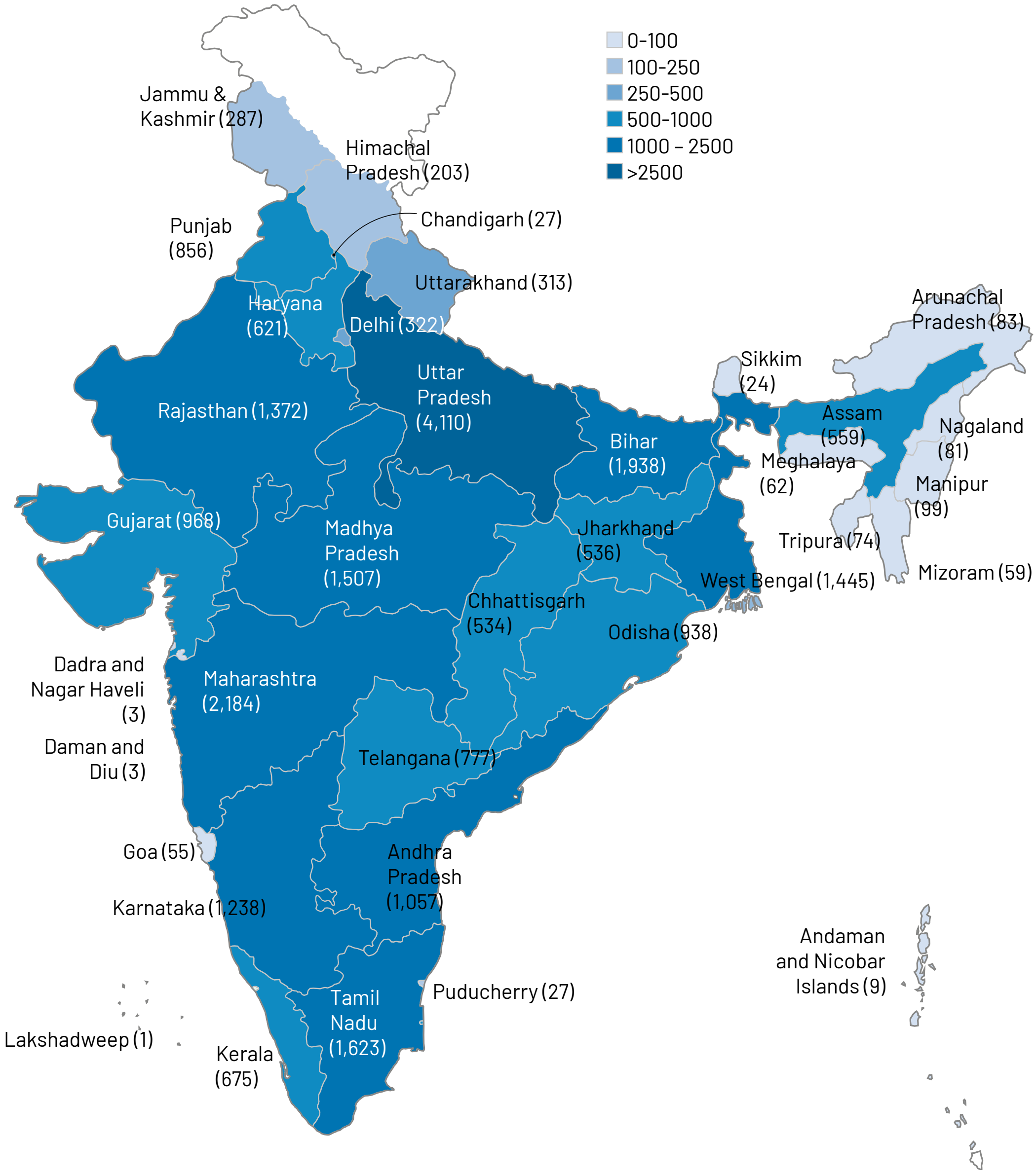
Source: Ministry of Petroleum and Natural Gas, 2021

2.2. LPG distributors

Government subsidy and policy push for clean cooking fuel, along with increasing urban population, have contributed to a growing consumption of LPG in India.[15] Consequently, the number of LPG distributors has also increased over the past decade, from 10,541 LPG marketing companies in 2010-11 to 24,670 in 2019-20 (Map 2).[16]

However, the increase is not equal for all states. In more urbanised states/UTs such as Delhi or Chandigarh, the number plateaued over the last decade. In Chandigarh, in 2010-11, the number of marketing companies was 27, which has remained unchanged in the last 10 years. Similarly, in Delhi, over the last 10 years, the number has only increased marginally, from 314 in 2010-11 to 322 in 2019-20. In contrast, in Uttar Pradesh, the number has increased significantly over the last decade from 1,299 in 2010-11 to 4,110 in 2019-20. Some other states such as Jharkhand and Bihar have also shown a four-fold increase.[17]

Map 2: State-wise number of LPG marketing companies (2019-20)



Source: Petroleum Planning & Analysis Cell, Government of India, 2021

3. Employment

It is difficult to estimate the total number of people employed in the entire oil sector value chain due to scattered nature of the data. However, an attempt has been made to estimate the employment in oil and gas companies, refineries, and marketing and distribution sector.

The central public sector oil and gas enterprises (CPSEs) provide permanent employment to slightly over 0.1 million people in 2019-2020.[18] The major shares of employment are in exploration and production (largely in ONGC), refining and marketing, accounting for about 28.9%, 24.4%, and 27.3% of oil CPSE jobs, respectively (Table 3). However, private sector now contributes about 20-25% of crude oil and gas production and has over 35% of refining capacity. Reliance India Limited and Nayara Energy Limited operate three large oil refineries and run 7,400 retail outlets across the country.[19,20] The data on employment provided by the private sector companies is not available.

To estimate the total permanent employment in oil and gas companies, including public and private sector, an employment factor approach has been considered, using CPSEs as the baseline. Going by the approach, the total permanent employees in the oil and gas companies is estimated to be 0.16 million. The actual numbers, however, are likely much higher due to large-scale use of contract workers and outsourcing of jobs in marketing and distribution (particularly retail).

Table 3: Employment in oil and gas companies

	Exploration and Production	Refining	Marketing	Others	Total
CPSEs	29,987	25,322	28,380	201,43	103,832
Private and JVs	9,996	18,456	19,722	11,088	59,262
Total	**39,983**	**43,778**	**48,102**	**31,231**	**163,094**

Source: Ministry of Petroleum and Natural Gas, 2021 (for CPSEs)

Note: 1. Does not include expats, foreign experts, contract workers and retail.; 2. Private and joint ventures (JVs) are estimated based on employment factor approach.; 3. Employment in CPSEs from Ministry of Oil and Natural Gas, 2021, and company annual reports of CPSEs

3.1. Refinery

The total permanent employees in oil refineries is estimated to be about 44,000 (Annexure 4). However, there is a high share of contract workers in the refining sector. While current estimates are not available, a report of the Labour Bureau of 2010[21] estimated that there are 58,894 contract workers in the refining sector across India.[22] This was nearly twice (1.7 times precisely) the number of permanent workers in the refinery (CPSEs) at that time (34,036 as per 2009-10 estimates).[23] If the ratio between contract and permanent employees is considered, then the total number of contract workers in the refineries currently can be estimated to be about 74,000. This is likely an underestimation, as the number of contract workers in the oil and gas sector is increasing.

Overall, about 0.12 million people are employed in refineries. Among public sector, IOCL has the highest employee strength, primarily concentrated in eastern and central parts of India. Among private sector, considering its scale of operation, RIL has the maximum employees. Overall, considering both public and private sector, the maximum number of employment in refineries are in Gujarat, accounting for nearly 41% of total refinery workers.

3.2. Oil retail

The employment in the retail sector—both public and private outlets—is estimated to be about 1.1 million as of 2020.[24] While retail outlets are spread across the country, their numbers are much higher in states such as Uttar Pradesh and Maharashtra. Other states with high workers share include, Karnataka, Gujarat, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Rajasthan, and Punjab. Overall employment in the oil retail sector is estimated to be over 0.1 million. A significant proportion of this are semi-skilled workers, and are mostly supported through basic wage rates.[25]

3.3. LPG Distribution

The total workforce in LPG distribution is estimated to be about 0.1 million.[26] The states with most concentration of workers include Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal, Rajasthan, Tamil Nadu, and Maharashtra. However, as discussed earlier, this is likely to see a declining trend in cities due to increased penetration of piped natural gas.

Like oil retail workers, the LPG distribution segment also includes at least 50% of semi-skilled workers, who are involved in loading, unloading, and delivery. While oil retail workers will need reskilling due to penetration of EVs, LPG distribution jobs are likely to reduce in many pockets due to reduced consumption of LPG as cooking fuel.

Overall, the total formal employment in the oil sector is estimated to be at least 1.4 million. The estimation on informal employment requires further work.

Table 4: Total formal employment in oil sector

Sectors	Formal employment
Oil and gas companies (excluding refineries)	119,316
Refineries	118,132
Oil Retail	1,105,488
LPG distribution	98,680
Total	**1,441,616**

Source: iFOREST analysis

4. Public revenue contribution

The share of oil sector (oil rents) to India's GDP has largely been declining since 2011. As compared to 1.36% in the reference year (2011), the sector's contribution to the country's GDP stands at about 0.4%, as per the latest estimates of 2019.[27] However, taxes from the oil and gas sector are a significant revenue source for the Government. The Centre's main source of revenue are the taxes, duties, and cess, while for the states/UTs the biggest source of revenue is sales tax/VAT on petroleum products. In 2019-20 (as per information computed from 16 major oil and gas companies), the total contribution of the petroleum sector to the Government exchequer was ₹ 5,554 billion (₹ 555,370 crore), of which, Centre had a share of over 60%, and the States/UTs' share was about 40% (Table 5).

The contribution of the oil and gas sector to the central government's revenue is as high as 17.2%. The sector contributes 7.5 % to the state governments' revenue. This huge reliance of the public exchequer on the oil and gas sector means reduced oil and gas consumption, especially petrol and diesel use in road transport that provides a bulk of the tax revenues, will have financial implications.

Table 5: Contribution of the oil sector to Centre and State/UT exchequer (2019-20)		
Contribution types	**Particulars**	**Amount (₹ Billion)**
Central Tax/ Duties on Crude oil and Petroleum products	Cess on Crude Oil	147.89
	Royalty on Crude Oil / Natural Gas	56.02
	Customs Duty	229.27
	NCCD on Crude Oil	11.3
	Excise Duty	2,230.57
	Service tax	0.17
	IGST	130.99
	CGST	68.31
	Others	0.88
Income tax, dividend to Central Government etc.	Corporate/ Income Tax	231.34
	Dividend income to Central Govt.	122.7
	Dividend distribution tax	54.62
	Profit petroleum on exploration of oil/ gas	59.09
Total contribution to central exchequer		3,343.15
Percentage contribution to central exchequer (as % of total revenue)		17.20%
State/UT Tax/ Duties on Crude oil and Petroleum products	Royalty on Crude Oil / Natural Gas	118.82
	Sales Tax/ VAT	2,004.93
	SGST/UTGST	73.45
	Octroi, Duties Incl. Electricity Duty	7.16
	Entry Tax / Others	4.05
Dividend / Direct tax etc.	Dividend income to State Govt.	2.15
Total contribution to state exchequer		2,210.56
Percentage contribution to state exchequers (as % of total revenue)		7.50%
Total contribution of oil and gas sector to the government revenue		5,553.7
Percentage contribution to the government revenues (as % of total revenue)		11.40%

Source: Petroleum Planning & Analysis Cell, Government of India, 2021

5. Transition challenges

The future of the oil sector in India in the coming years, including its implications for a just transition, is related to two major end uses:

- Road transportation, including freight and passenger vehicles; and,
- Cooking fuel.

5.1. Road transportation

Energy use in India's transport sector has increased nearly five times in the past three decades, consuming more than 100 million tonnes of oil equivalent (MTOE) in 2019. Unlike electricity and other industrial sectors which have a relatively diverse source of energy mix, the transport sector is heavily reliant on oil, with 95% of its fuel demand being met by petroleum products.[28]

Growing urbanisation, coupled with industrial growth, will trigger growth in the transportation sector, and consequently, oil consumption, under business-as-usual scenario. The projection of oil demand by International Energy Agency (IEA) in India does not show a significant dip in the next two decades due to massive increase in freight transport (Table 6).[29] Only in the Sustainable Development Scenario (SDS), there is a moderate growth in oil demand. While growth in freight trucks is projected even under SDS, it is assumed that there will be increase in hybrid, electric, hydrogen and natural gas freight vehicles.[30]

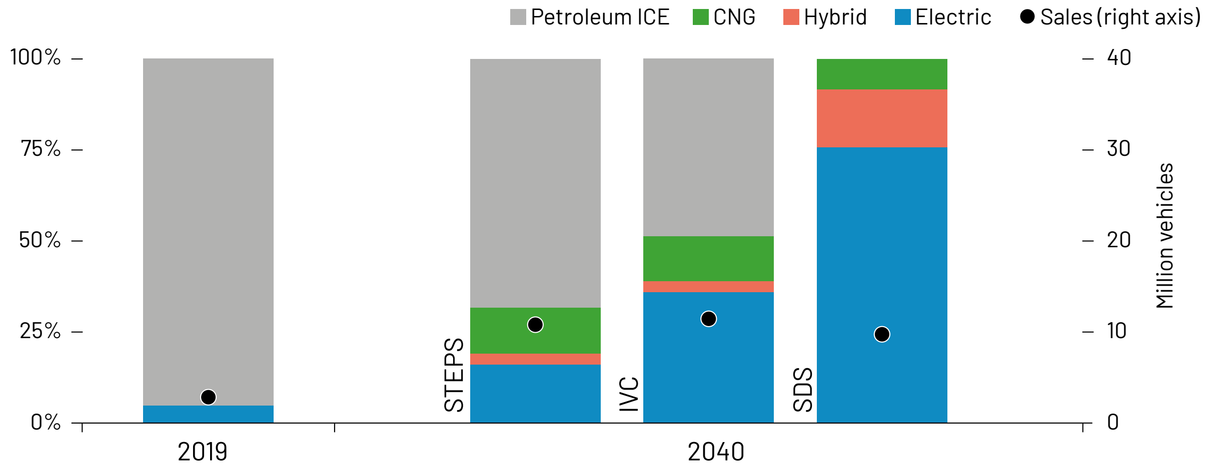
Table 6: Oil demand under STEPS, IVC and SDS

Oil demand (mb/d) by various sectors	Current	STEPS*		IVC*		SDS	
	2019	2030	2040	2030	2040	2030	2040
Road transport	1.9	2.9	3.8	3.0	3.8	2.4	2.1
Aviation and shipping	0.2	0.4	0.6	0.4	0.6	0.3	0.4
Industry and petrochemicals	0.9	1.5	1.8	1.4	1.7	1.2	1.3
Buildings	1.0	1.3	1.4	1.4	1.5	1.4	1.1

Source: International Energy Agency, 2021; *STEPS: Stated policies scenario; *IVC: India vision case

However, if we just consider passenger vehicles, the reliance on oil shows a decrease under all three scenarios. In fact, under SDS, the passenger cars move out of diesel and petrol.

Figure 3: Estimates of passenger car sales under various scenarios



Source: International Energy Agency, 2021

Considering the diversification of fuel mix for freight vehicles, and increase in electric cars, 2Ws and 3Ws, two impacts can be assumed in context of just transition:

- There will be reduction in demand for diesel and petrol production by refineries, which are currently the main output; and,
- There will be reduction in the number of petrol pumps or modification of these infrastructures in commensurate with electrification of vehicular fleet.

For the first one, as per current Government projections, there is no reduction in refinery capacity or output in the next 30 years. The IEA (2021) also suggests an increase in refining capacity till 2040.[31] However, other modelling studies indicate significant reduction in oil demand by 2050.[32] Overall, there will be changes in the product mix of the refinery sector. This will reduce refining capacity and lead to significant technological changes. Hence, both job loss and reskilling requirements should be anticipated.

There will be considerable implications for petrol pumps. If passenger vehicles move to electricity, then either the number of pumps will go down or they will be modified to serve electric vehicles. In the first scenario, there will be job losses, and in the second, reskilling will be required.

5.2. Cooking fuel

In a bid to adopt and use clean cooking fuel, the Government has been aggressively pushing LPG. At the end of first three phases of the Pradhan Mantri Ujjwala Yojana (PMUY) scheme in 2019, about 94% of the Indian households have an LPG connection.[33] Besides LPG, other modes of cooking fuel such as piped natural gas (PNG), biogas and improved cookstoves are also being promoted and expanded at various levels.[34]

Considering such pathways of clean cooking fuel, the IEA (2021) has projected massive increase in the use of LPG and modest increase in natural gas and electricity (Table 7).

Table 7: Share of population using various cooking fuels under STEPS, IVC and SDS

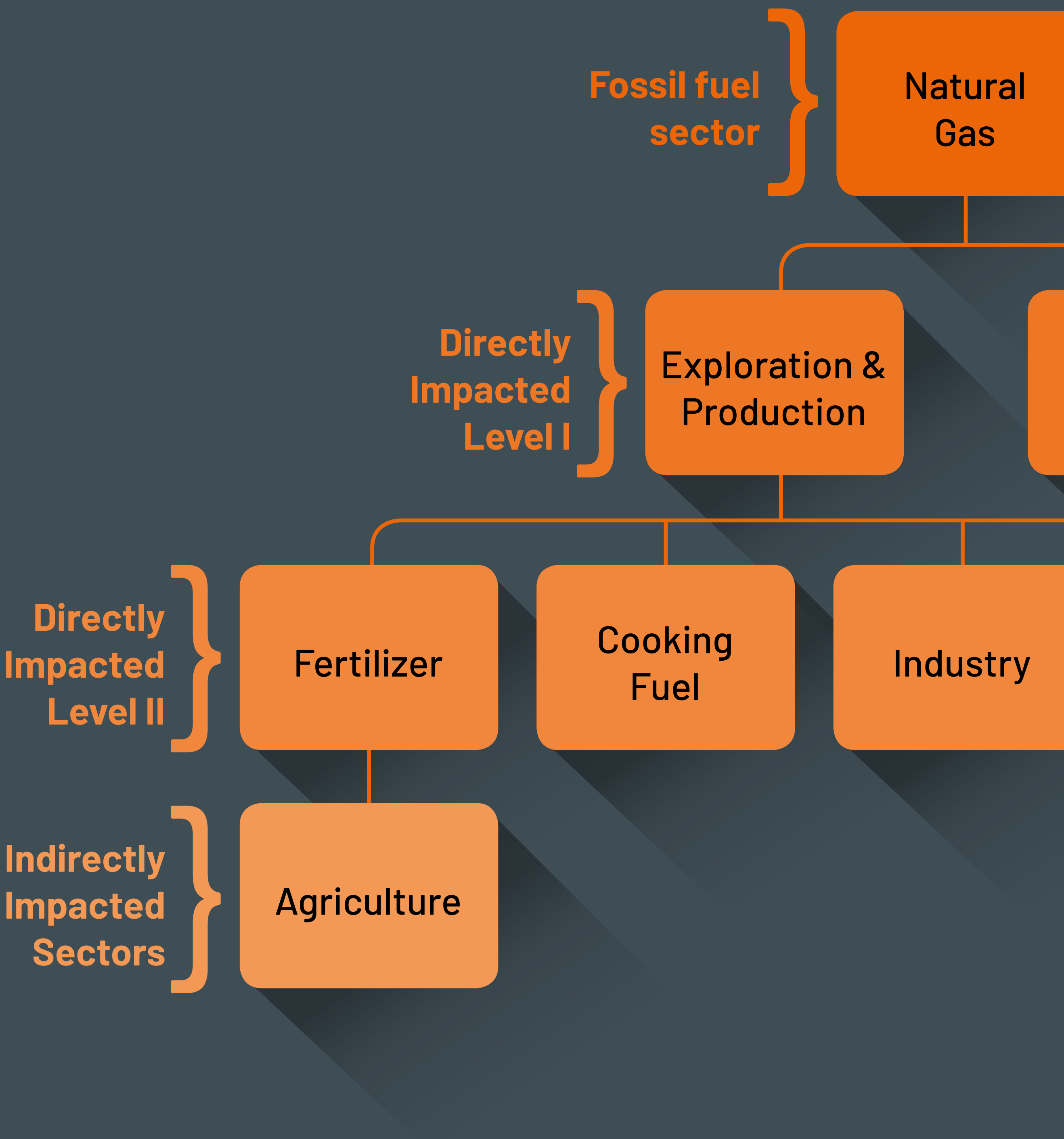
Cooking fuel source	Share of population reliant (%) in 2030	
	STEPS	IVC/SDS
Traditional fuel-biomass	33	0
LPG	54	76
Natural gas	6	9
Improved biomass cookstoves	2	7
Other clean	5	8

Source: Adopted from International Energy Agency estimates, 2021

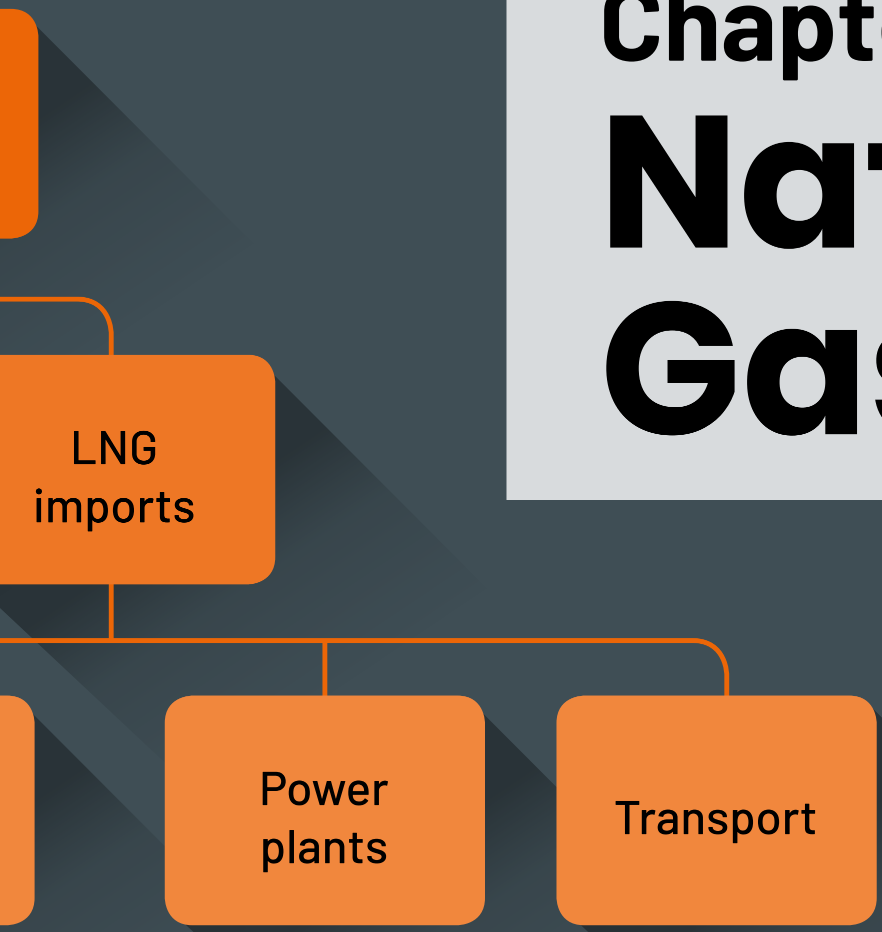
However, a review of the existing PNG network suggests that urban India will move to PNG. The Government is planning to spend ₹ 120,000 crore over the next 10 years to expand the city gas distribution (CGD) network across the country to cover 407 districts, and for about 70% of the population. This includes households as well as industrial and commercial users.[35] Similarly, electric cooking is slowly finding a foothold due to affordability.[36] From a just transition perspective, therefore, LPG distributing companies, along with their workforce, will be impacted.

Overall, the scoping of the oil sector brings out some of the opportunities and challenges of a just transition.

- The transition in the downstream sectors such as refining (with reduced production of petrol and diesel), marketing and distribution will not see a huge job loss, but the primary requirement will be retraining and reskilling of the workforce.
- In oil refineries, the expected demand downturn of petrol, diesel, and LPG in the coming years, can be substituted by adaptation of oil refineries to produce other 'modern' fuels.[37] The existing workforce can be retrained/upskilled, accordingly.
- Electrification of vehicle fleet, including two and three wheelers, passenger cars, and a proportion of freight vehicles, will require redesigning the retail infrastructure. The Government is already planning to set up at least one EV charging kiosk across 69,000 petrol pumps in India.[38] As EV sales and use go up, the publicly available alternative fuel infrastructure must increase to the tune of 1 charger per 10 cars (European Commission directive 2019)[39]. As the infrastructure gets redesigned, the workforce can be reskilled in phases, accordingly.
- For the LPG distributing network, there will be job losses and the need for alternative employment. However, this should be a lesser problem considering comparatively low workforce (overall about 1 lakh), and the fact that the transition can start with major cities.
- Finally, one of the key challenges for a transition in the oil sector will be substitution of public revenue. Many of the States/UTs make up for their revenue deficit through sales of petrol and diesel. For the Centre, too, the excise duty is a very significant part of revenue. The Government, in near term, will have to plan a taxation policy to offset the loss of sales taxes from petrol, and in the mid-term for loss of taxes from diesel.


Fossil fuel sector
Natural Gas
Directly Impacted Level I
Exploration & Production
Directly Impacted Level II
Fertilizer
Cooking Fuel
Industry
Indirectly Impacted Sectors
Agriculture

Chapter 3
Natural Gas

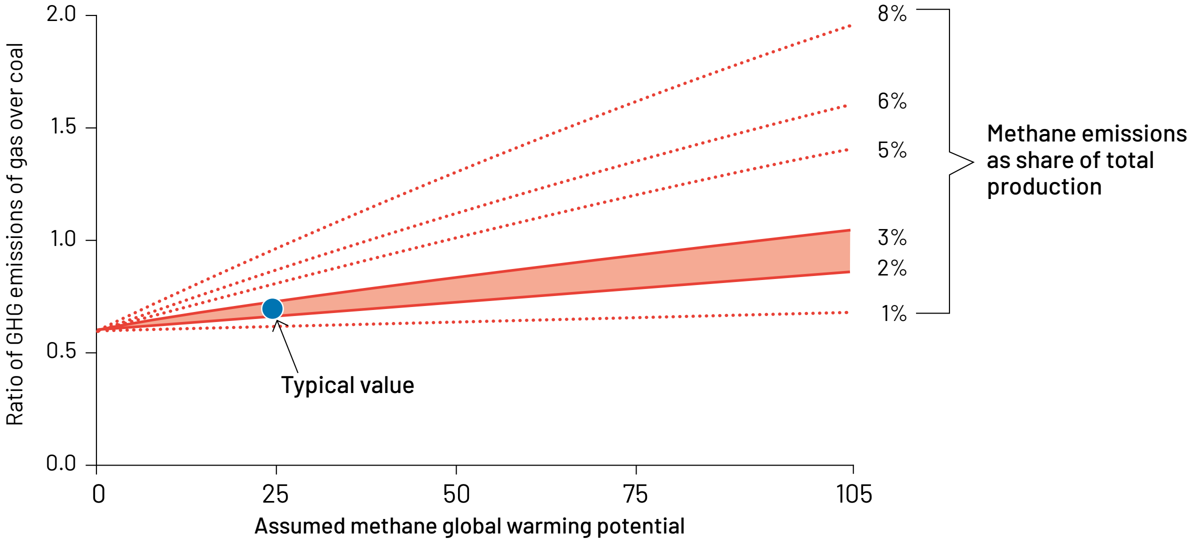


Among the three fossil-fuels, the natural gas sector is likely to see the least disruptions. Both policy makers and energy experts envision an increased use of natural gas to meet the local pollution and GHG emission reduction targets.[1] All the net-zero models project 3-4 folds increase in natural gas by 2050.[2] The Government of India has also set a target to increase the share of natural gas in India's energy mix from current 6% to 15% by 2030.[3] Natural gas consumption, therefore, is projected to increase through city gas distribution (CGD), industrial sector, as well as the power sector.[4]

However, natural gas use has significant implications for global warming, though there is uncertainty regarding its actual contributions, in particular the level of methane emissions – whether by accident or by design – from well-to-burner. A 2019 study published in Nature found that methane leaks from the fossil fuel industry were underestimated by at least 40%.[5]

Methane is a more potent greenhouse gas than CO_2, but has a lower half-life than CO_2. The Global Warming Potential (GWP) of methane, compared to CO_2, averaged over 100 years is 25. Averaged over 20 years, the GWP of methane rises to 84. Some studies, however, peg the 20 years GWP of methane as 105.[6] As the GWP of methane is high, any significant release of methane during the life cycle of natural gas increases the climate footprint significantly. It is estimated that at a GWP of 105, if 3% of natural gas production is emitted from well-to-burner, then gas loses all its GHG emissions advantage over coal (Figure 1).[7] The growth in natural gas use worldwide, therefore, will largely depend on better understanding regarding its global warming impacts.

Figure 1: GHG emissions of coal vs. natural gas

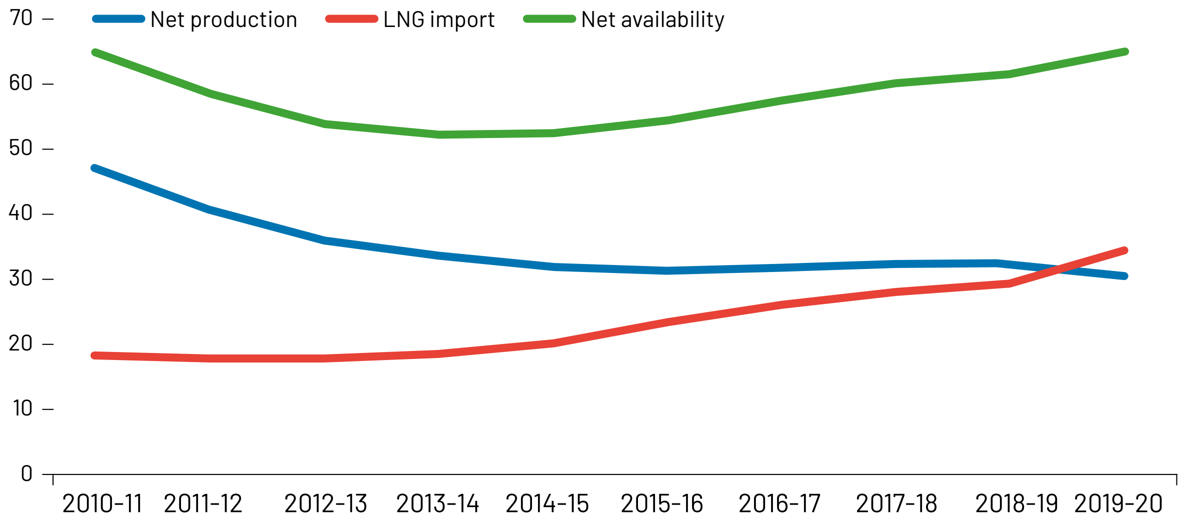


Source: Figure adopted from International Energy Agency, 2012

1. Production and consumption

While India is ambitious of a 'gas economy', the country until now is heavily reliant on natural gas imports to meet its demand. For instance, in 2019-20, India produced about 30.3 billion cubic meters (BCM) of natural gas and the import was nearly 34 BCM. In fact, over the past decade, the import of natural gas has increased steadily, from 18 BCM in 2011-12 to about 34 BCM in 2019-20. The domestic production has gone down during this period, from 46.5 BCM in 2011-12 to 30.3 BCM in 2019-20.[8]

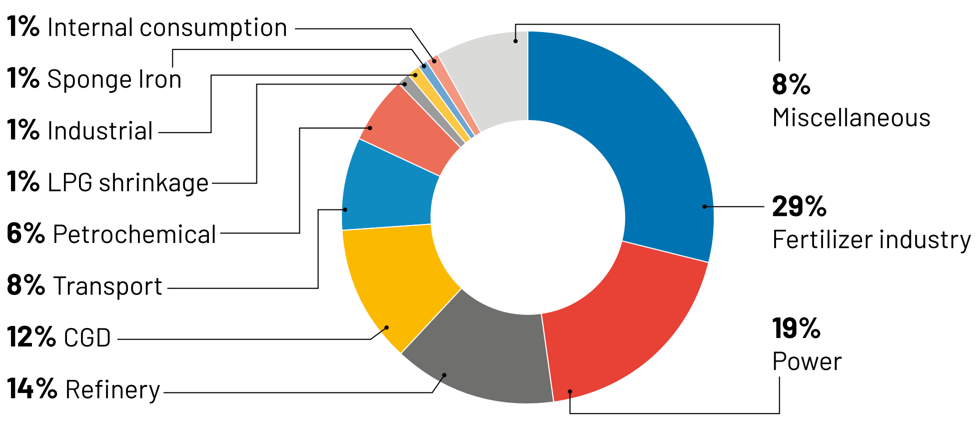
Figure 2: Production, import and availability of natural gas (BCM)



Source: Petroleum Planning and Analysis Cell, 2021

With respect to consumption, it is primarily driven by the demand of the fertilizer sector. The Indian fertilizer industry is largely dependent on natural gas as a feedstock and fuel.[9] In 2019-20, the sector accounted for 29% of natural gas consumption. The other key sectors are power, refinery and city gas distribution (CGD). The transport sector, accounts for about 8% of natural gas consumption (Figure 3).

Figure 3: Sector-wise consumption of natural gas



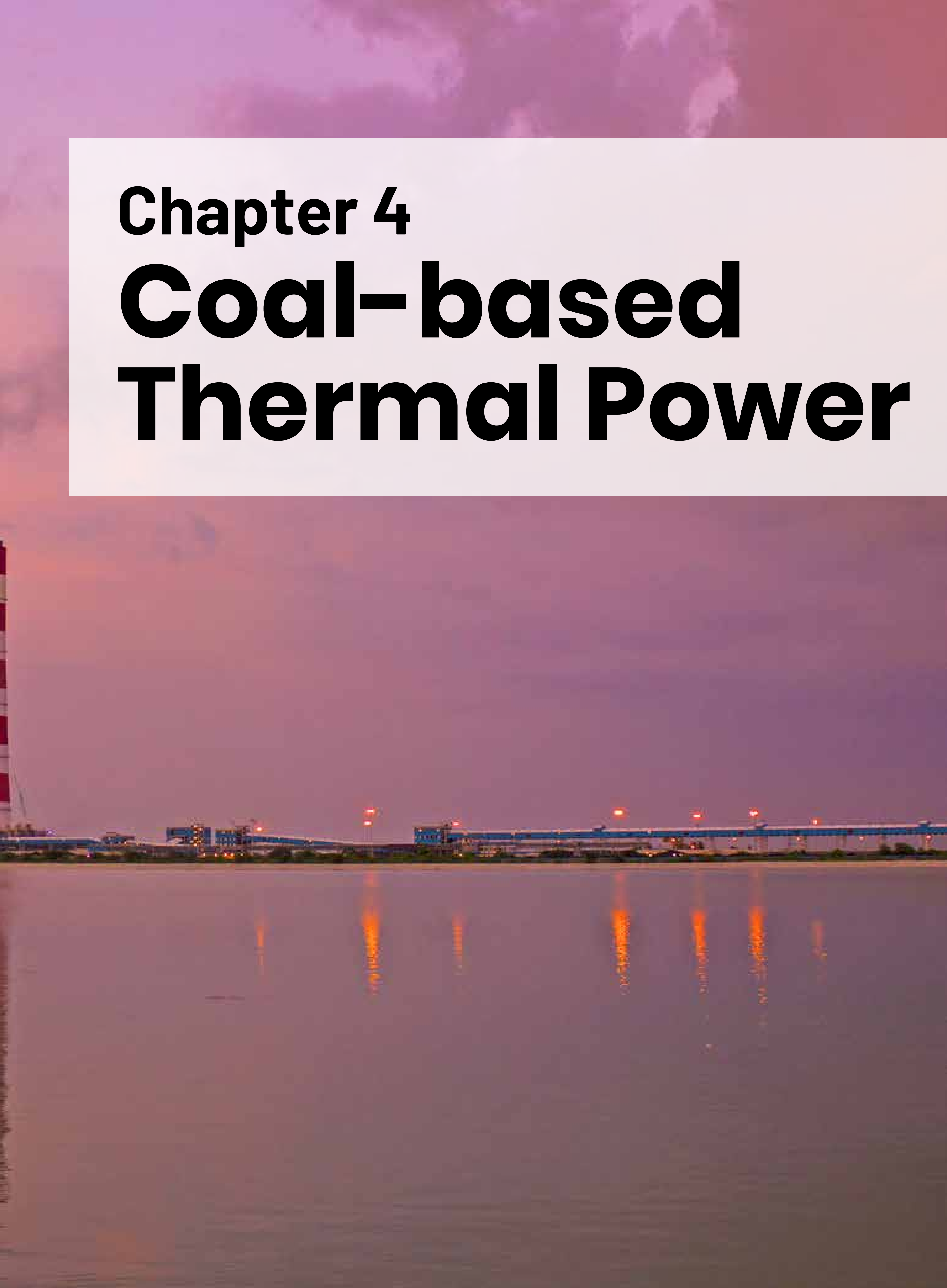
Source: Ministry of Petroleum and Natural Gas, 2021

2. Transition challenges

Presently, the gas sector doesn't seem to have major transition challenges because of the projected growth in this sector till 2050. In any case, natural gas production is not a major issue as India can easily increase gas production and still meet its net zero targets. There will be, however, implications on the imports of natural gas due to an interplay between pricing of LNG and the competitiveness of alternative technologies. If the alternatives like hydrogen and electricity becomes cheaper than imported LNG, then gas use will not grow as much as is being projected by various agencies.

INDUSTRIES

Chapter 4
Coal-based Thermal Power



The thermal power sector is the one that is most inextricably linked to coal, and is at the threshold of a transition. While coal-based thermal power still contributes about 72% of the country's electricity generation,[1] the sector is increasingly losing its competitive edge due to the cost-competitiveness and reliability of electricity supply from renewable energy (RE) sources.

The installed cost and tariffs of utility-scale solar photovoltaic (PV) plants in India have fallen by 85% since 2010, coming down to ₹ 2.50-3.00/kWh (US$ 0.35-0.45/kWh) by 2019. This is already 20% to 30% cheaper than the cost of power from existing coal plants. This trend is widely expected to continue, with solar power prices expected to fall to around ₹ 2.00/kWh (US$ 0.025/kWh) or even lower by 2030, while the cheapest pithead coal power price is likely to rise to ₹ 4.85/kWh (US$ 0.07/kWh) by that time.[2] In fact, in the past five years, solar PV capacity has grown at a rate of about 60% (and wind at around 10%), outpacing the 7% growth in overall installed capacity.[3]

At the same time, the reliability of uninterrupted energy supply from renewable sources is also growing due to advancement in battery storage. In May 2020, in the first ever "round-the-clock" RE auction (RE with battery storage), the average tariff quoted was ₹ 4.30/ kWh (US cents 6.1/kWh), which is the cheapest renewable-plus-battery storage tariff anywhere in the world. At this tariff, renewable plus battery storage will outprice most new coal-based power plants.[4]

The cost competitiveness of RE has also worsened the burden of non-performing assets in the thermal power sector. The installed capacity of coal-based power had grown exponentially in the last one and a half decade, particularly since the end of the 10th five-year plan (2002-07). Between 2007 and 2017, 121,042 MW of coal-based power was installed.[5] This did overshoot the actual demand, and eventually, the capacity remained underutilised with plants running at a 60% to 65% capacity. With thermal power companies forming a major share of the stressed assets of banks, the investor sentiment has been further hurt.

The future projections of coal-based thermal power are reflecting this sentiment. It has now become clear that there will be no net growth in the coal-based power sector going ahead, barring only the ones that are already currently under construction.[6]

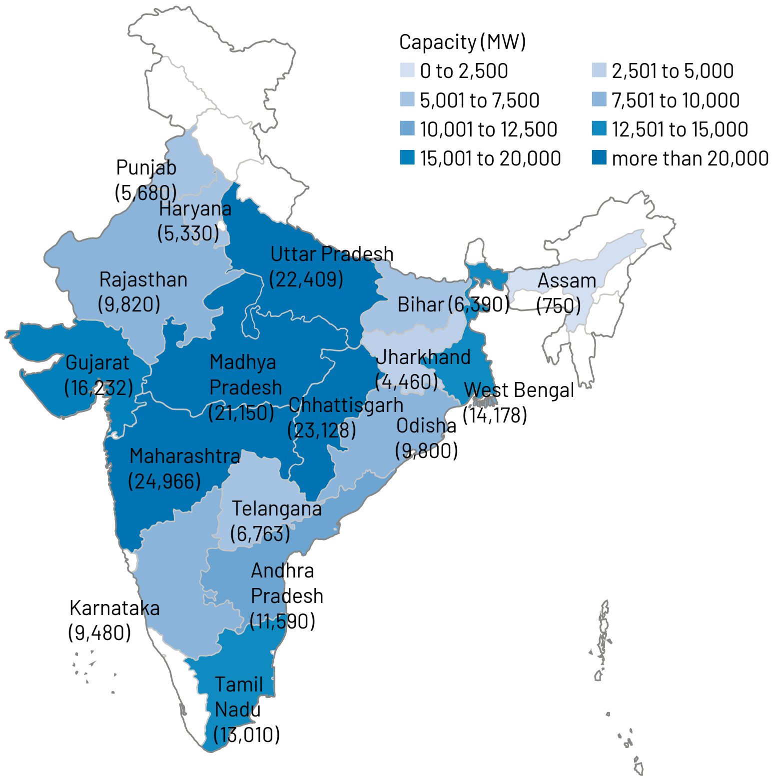
Finally, the GHG emission of the coal-based power sector has made its transition inevitable. India is the third-largest emitter of CO_2 globally,[7] and coal-based power is responsible for 70% of India's energy sector CO_2 emissions.[8] Between 2011-12 and 2015-16, the CO_2 emissions from the power sector grew at a compound annual growth rate (CAGR) of 7.3%. It has since grown at 3.26% until 2021, as per projections.[9]

In the above context, it is essential to evaluate the just transition scenario for the thermal power sector in India.

1. Spatial distribution

India currently has 189 operational coal-based thermal power plants (TPPs), with a cumulative installed capacity of 205,136 MW (2019-20). Most of the TPPs are concentrated in seven states—Maharashtra, Chhattisgarh, Uttar Pradesh (UP), Madhya Pradesh (MP), Gujarat, and Tamil Nadu—which account for nearly 66% of the total installed capacity (Map 1). Maharashtra has the highest installed capacity (24,966 MW), closely followed by Chhattisgarh (23,128 MW), Uttar Pradesh (22,409 MW), and Madhya Pradesh (21,150 MW).

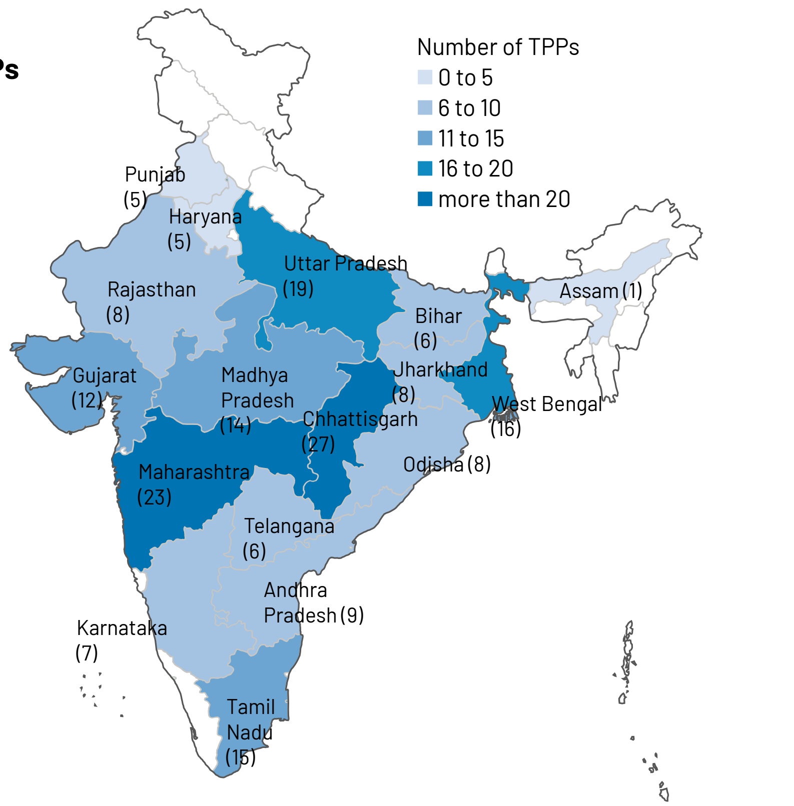
Map 1: State-wise distribution of TPPs (capacity)



Source: iFOREST analysis

With respect to numbers, 60% of the TPPs are concentrated in six states (Map 2). Chhattisgarh has the highest number of TPPs (27) in the country, followed by Maharashtra (23), Uttar Pradesh (19), West Bengal (16), Tamil Nadu (15) and Madhya Pradesh (14).

Map 2: State-wise distribution of TPPs (number)

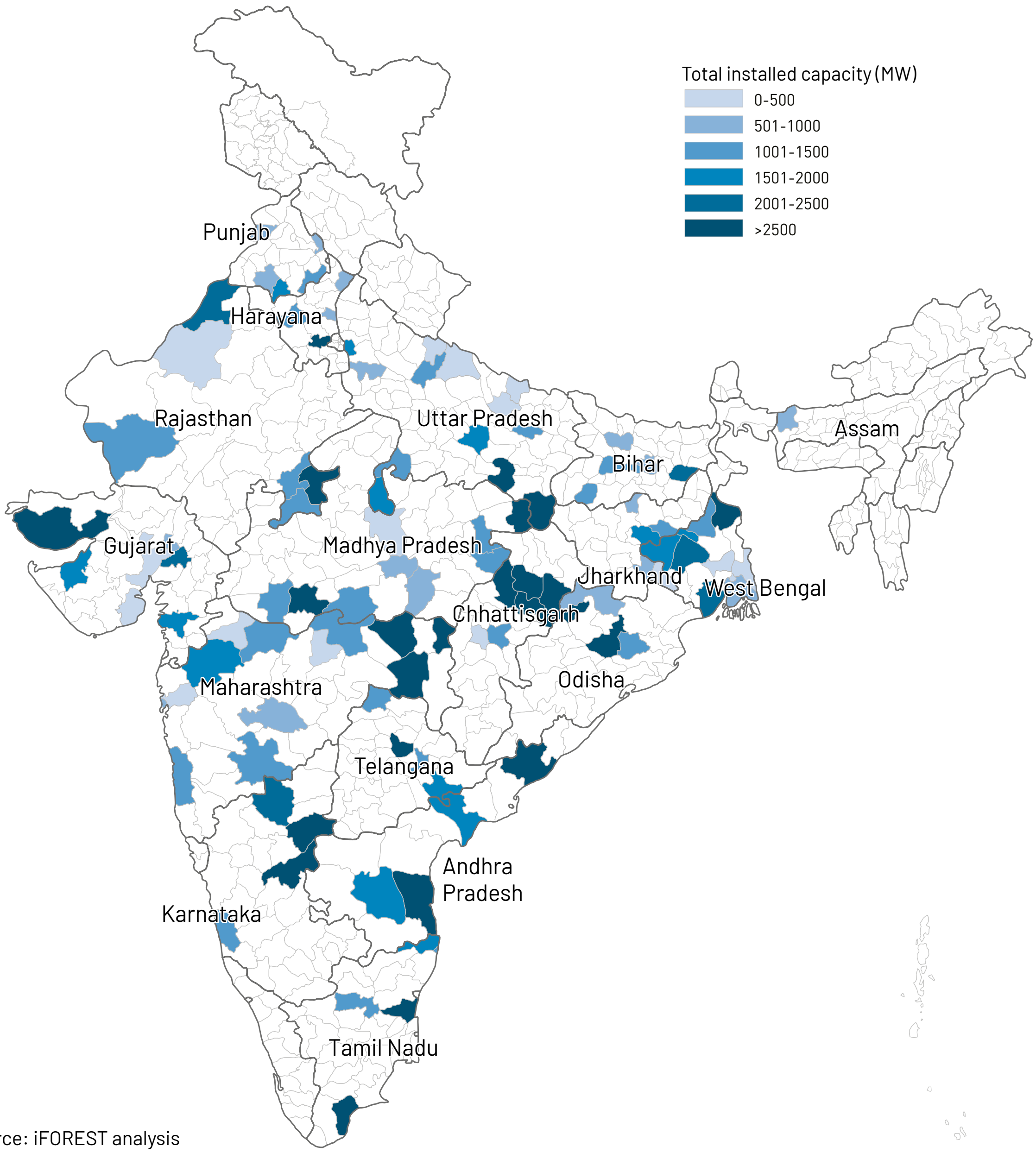


Source: iFOREST analysis

While coal-based power plants are spread out across various states, a closer look into the districts show that there is a higher concentration of these units in the coal-rich regions or in the coastal areas due to access of domestically produced or imported coal. These include, the coal districts of Chhattisgarh, Odisha, Madhya Pradesh and Maharashtra, and the coastal districts of Gujarat and Andhra Pradesh (Map 3 and 4).

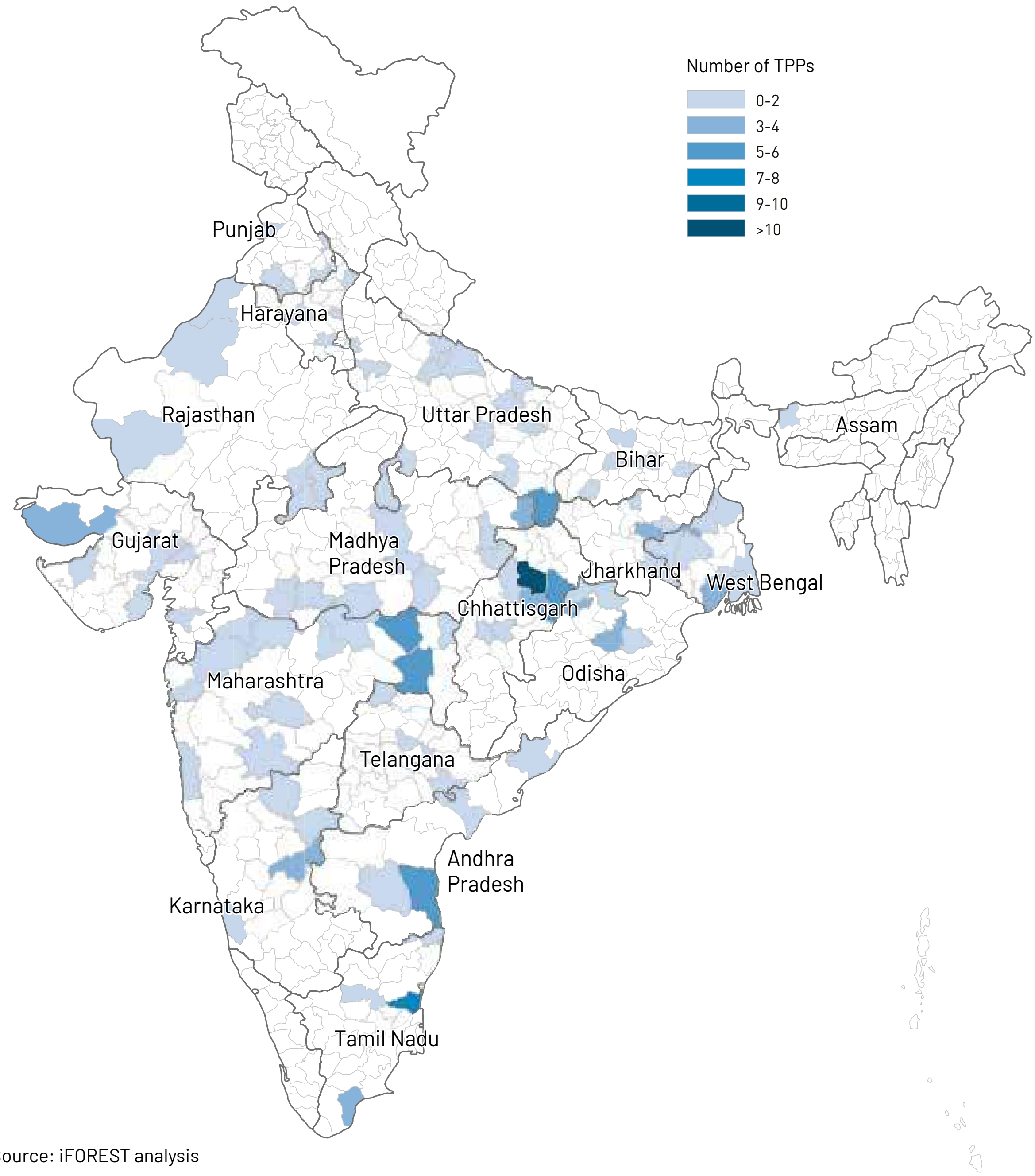
In fact, the power production capacity in India is largely concentrated in just 25 districts. These districts account for about half (precisely over 47%) of the country's total installed coal-based power capacity as well as the number of units. With respect to installed capacity, Singrauli (Madhya Pradesh) has the highest share. In terms of number of units, Korba (Chhattisgarh) has the maximum number of power plants (Table 1). The analysis also shows that most of the top power producing districts are the top coal mining districts as well. These include, Korba, Raigarh, Singrauli, Sonebhadra, Angul, Jharsuguda, and Chandrapur, among others.

Map 3: District-wise distributions of TPPs (capacity)



Source: iFOREST analysis

Map 4: District-wise distributions of TPPs (number)



Source: iFOREST analysis

Table 1: Top 25 coal-based thermal power districts (capacity-wise)			
State	**District**	**Number of TPPs**	**Installed capacity (MW)**
Andhra Pradesh	Nellore	5	5,140
	Visakhapatnam	2	3,040
Chhattisgarh	Bilaspur	1	2,980
	Janjgir-Champa	4	5,440
	Korba	15	7,438
	Raigarh	5	5,400
Gujarat	Kutch	4	9,160
Haryana	Jhajjar	2	2,820
Karnataka	Bellary	3	2,560
	Raichur	2	3,320
	Vijayapura	1	2,400
Madhya Pradesh	Khandwa	1	2,520
	Singrauli	4	11,240
Maharashtra	Chandrapur	5	4,780
	Gondia	1	3,300
	Nagpur	6	7,176
Odisha	Angul	3	4,660
	Jharsuguda	3	3,290
Rajasthan	Baran	2	3,640
Tamil Nadu	Cuddalore	7	4,690
	Tuticorin	4	3,550
Telangana	Karimnagar	2	2,663
Uttar Pradesh	Prayagraj	2	2,640
	Sonbhadra	5	9,924
West Bengal	Murshidabad	2	3,700

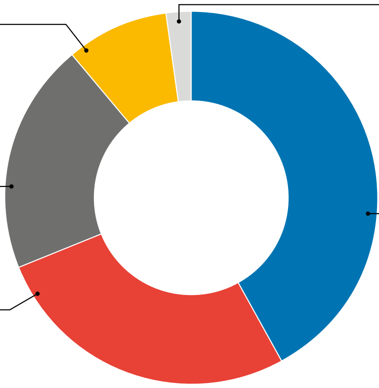
Source: Central Electricity Authority, 2020

2. Power Consumption

India is the third largest power consuming country globally, next only to China and the United States (US)[10]. The share of coal in power generation has been consistently around 76% on an average over the last five years.[11] Industry sector is the biggest consumer of power, accounting for 42%. This is followed by residential, agricultural, and commercial uses (Figure 1).

Among the states and Union Territories (UTs), Maharashtra is the biggest consumer (139,488 GWh in 2019), followed by Gujarat and Uttar Pradesh.

Figure 1: Sector-wise power consumption



Source: NITI Aayog Energy Dashboard

Table 2: State-wise electricity consumption for top 20 states (2019)

State	Consumption (GWh)
Maharashtra	139,488
Gujarat	110,161
Uttar Pradesh	101,735
Tamil Nadu	98,257
Karnataka	75,300
Odisha	70,205
Madhya Pradesh	69,234
Rajasthan	67,805
Andhra Pradesh	63,342
Telangana	61,640
Punjab	52,364
West Bengal	50,199
Chhattisgarh	44,749
Haryana	44,077
Delhi	29,171
Jharkhand	26,815
Kerala	22,283
Bihar	21,198
Uttarakhand	12,495
Jammu and Kashmir	9,637

Source: NITI Aayog Energy Dashboard, 2021

Box 1: Captive power plants

Captive power plants (CPPs) are a unique feature of India's industrial landscape. Almost all major industries have CPPs as the main source of electricity or as a backup to the grid supply. At the end of 2019, there were 2,861 existing CPPs with a combined capacity of 69.9 GW. In addition, 230 CPPs of 16.6 GW capacity were under construction.

Overall, India currently has 3,100 CPPs with a combined capacity of about 86.4 GW (Table 3). About 90% of these plants are less than 50 MW in size; only 0.8% have more than 500 MW capacity (Table 4).

A majority, about 61.5%, of the captive power capacity is coal-based. This is followed by natural gas at 15.4% and biomass at 8.5%. However, wind and solar also have a combined capacity of 9.1%. For plants constructed after 2019, the share of solar is about 12%.

Table 3: Capacity of CPPs

CPP type	Current capacity (MW)	Upcoming capacity (MW)	Total capacity (MW)	Share of total capacity (%)
Coal (including lignite and petcoke)	40,737	12,456.7	53,194	61.5
Gas	12,360	936	13,296	15.4
Diesel	2,309	170	2,479	2.9
Biomass	6,991	371.5	7,363	8.5
Wind	5,364	44	5,408	6.3
Solar	1,737	702	2,439	2.8
Others	361	1,901	2,262	2.6
Total	69,859	16,581	86,440	100

Table 4: Size distribution of CPPs

CPP size	Existing plants	Upcoming plants	Total	Share of total (%)
Less than or equal to 5 MW	1,355	38	1,393	45.1
5-10 MW	370	35	405	13.1
10-50 MW	883	106	989	32.0
50-100 MW	129	15	144	4.7
100-500 MW	108	28	136	4.4
> 500 MW	16	8	24	0.8
Total	2,861	230	3,091	100.0

The CPPs are cost-effective due to the electricity tariff structure. Under this structure, the industrial and commercial users are charged higher to cross-subsidise residential and agricultural customers. With solar and wind becoming cheaper and 24x7 electricity from RE becoming a reality due to the falling cost of storage, a large number of smaller CPPs can be moved to renewable energy. This can also be facilitated by the open access policy, under which large consumers can install off-site renewable power plants and transfer electricity by paying grid charges.

Along with the old power plants, shifting older and smaller coal-based CPPs to renewables will also be an economically sensible move.

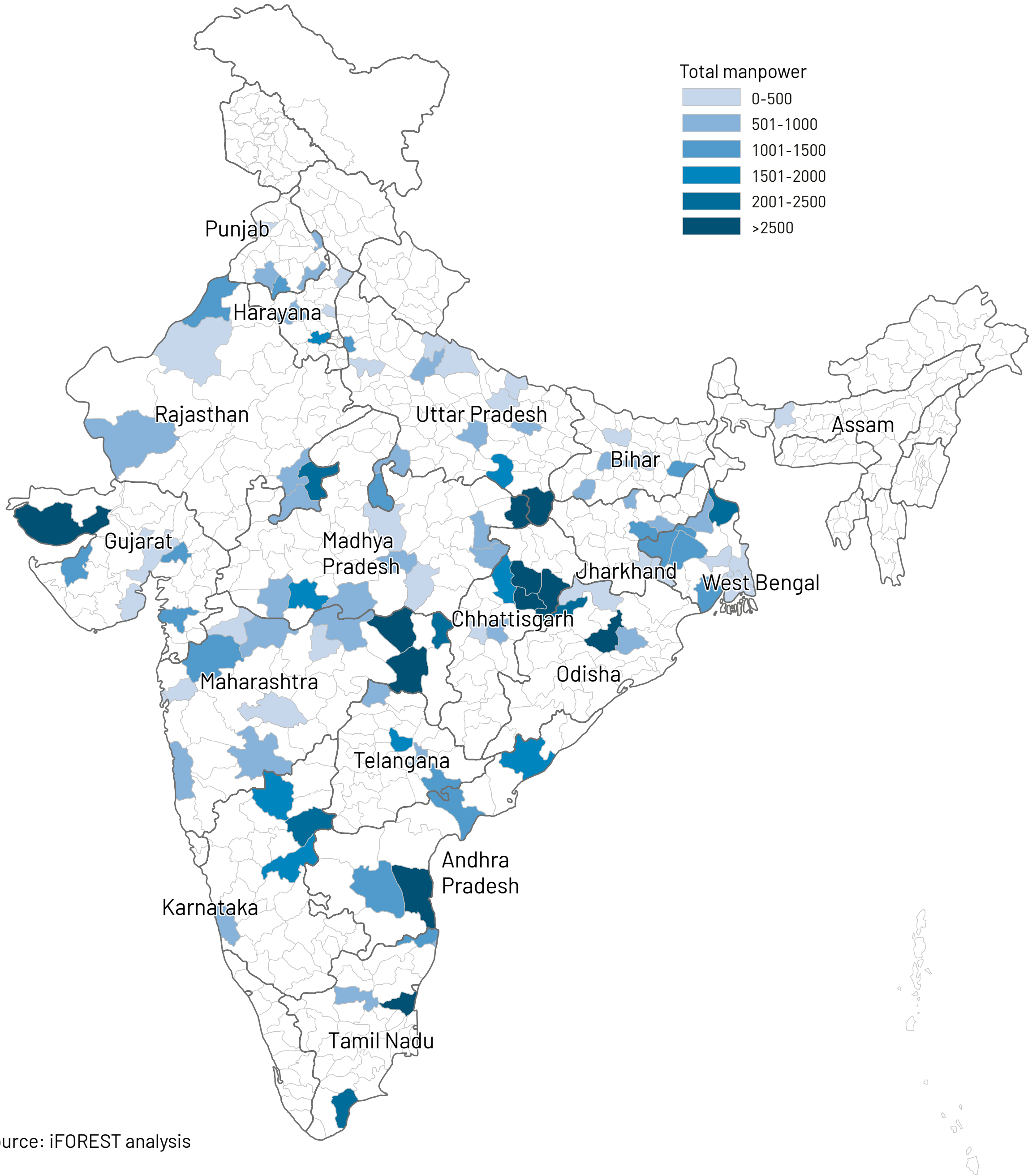
Source: Bhushan, C. (2017, October 31). End of Coal. Down To Earth. https://www.downtoearth.org.in/coverage/energy/the-end-of-coal-58909,

3. Employment

The manpower in the coal-based TPPs has been estimated considering the estimation norm of the Central Electricity Authority (CEA), on a plant-to-plant basis. This standard norm includes estimation for both regular and contractual employment.[12]

Based on such an approach, the overall employment is estimated to be about 0.13 million. Of this, about 57% of the manpower is concentrated in the top 25 districts (Map 5). The sector, being largely mechanised, has a relatively low share of informal workers.[13]

Map 5: District-wise distribution of estimated manpower



Source: iFOREST analysis

4. Future trends and just transition scenario

The coal-based thermal power sector is poised for a steady decline in the coming years. This is primarily triggered by three factors:

- Growing cost-competitiveness of RE, particularly solar and wind;
- Growth of utility-scale RE and assurance of round-the-clock supply, backed by growth in battery storage capacity; and
- Strengthening of the grid infrastructure, boosting flexibility in operations.

All of these are being backed by Government policies and strong market support. The RE boom in the last decade has been a response to the Government of India's ambitious target to create 175 GW of RE capacity by 2022. The Government has now set a further ambitious target of 450 GW of RE by 2030, and has simultaneously announced increasing storage capacity.[14]

Besides the Centre, some of the State Government's such as Chhattisgarh, Karnataka, and Gujarat have also announced no new coal power plant policies. Some states such as Karnataka are considering a planned phase-out.

The power industry has also recognised the opportunity. For instance, National Thermal Power Corporation (NTPC)—the country's largest power utility—plans to have a minimum of 32,000 MW capacity through RE sources by 2032, constituting nearly 25% of its overall power generation capacity.[15] The company is investing heavily on research and development (R&D) to this end.[16]

Overall, it has been projected that RE, along with battery storage, will see an exponential growth in both share of installed capacity and electricity generation.[17]

Therefore, for districts where the coal-based power industry is concentrated, planning a just transition should start. Considering the geographic spread and age of TPPs, following are some of the immediate opportunities:

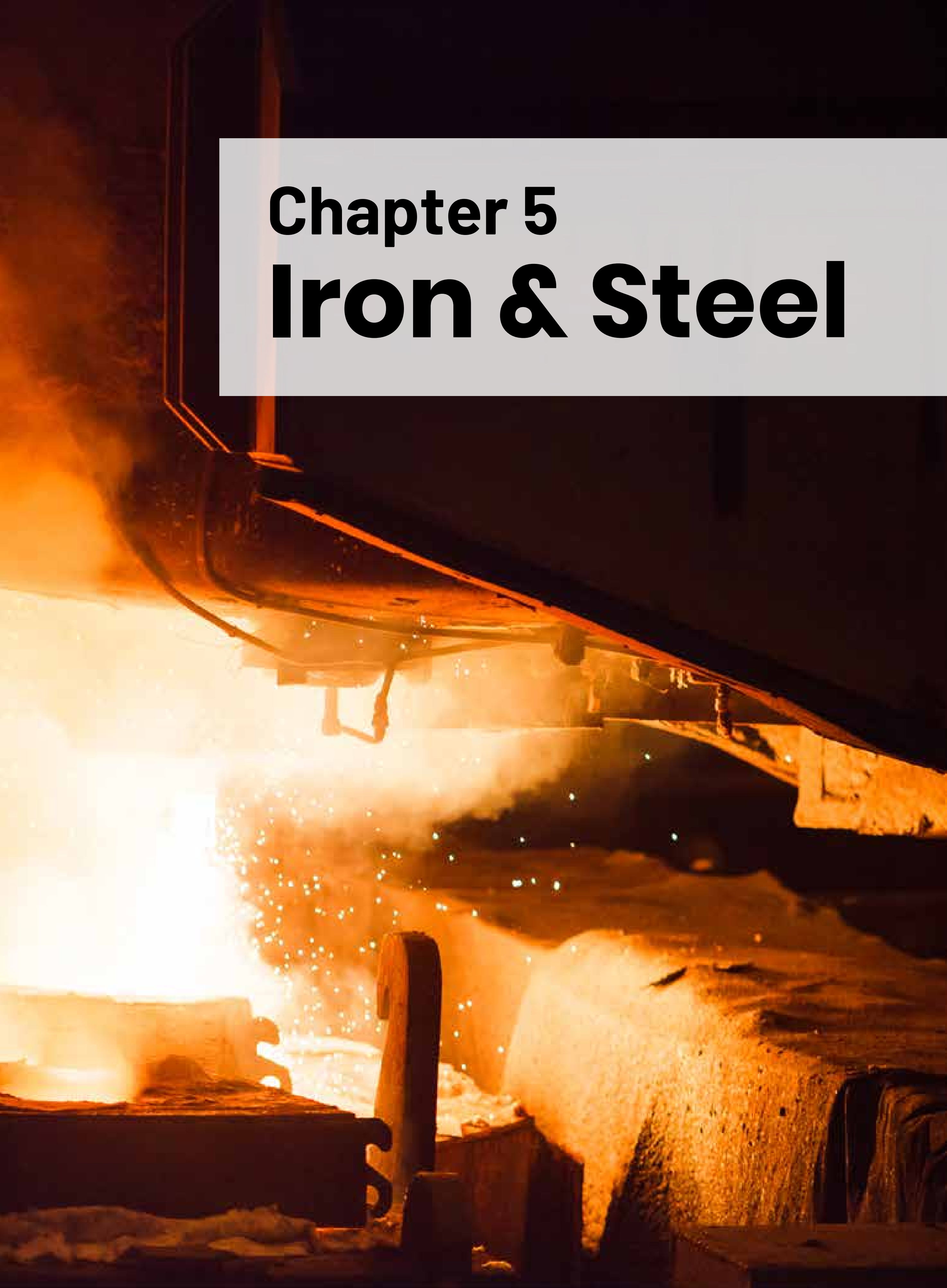
- The states and districts with the highest concentration of TPPs should start planning a phasing down of coal-based power plants in the coming years. This can be done based on their operational efficiency and age.
- About 30% of the country's operational TPPs (59 in total) were commissioned before 1995. These TPPs have a cumulative installed capacity of 73,540 MW, which is about 36% of the total installed capacity (Table 5). The Centre and the states can start planning their phasing out considering their declining efficiency and costs of 'must run' status.
- With respect to transition of workers, the thermal power industry will have far fewer challenge than the coal-mining sector as the former has a lesser number of regular/formal workers and a much lesser challenge of the informal workers.
- The transition of workers will be primarily a combination of retraining and reskilling, pension/early retirement compensations, and a provision of temporary transition assistance funds.
- Also, since many of the top coal and thermal power districts/regions overlap, it is only meaningful to plan a coal mining and thermal power transition in these regions together, so that integrated plans can be made, and effective outcomes can be achieved.

Overall, a just transition policy scenario for India should integrate components of a spatio-temporal phase-out plan for coal-based power, along with coal mining, to meet the CO_2 reduction targets, while not compromising on the country's economy and energy security.

Table 5: State-wise coal-based power plants installed more than 25 years ago	
State	**No. of plants installed before 1995**
Andhra Pradesh	2
Bihar	3
Chhattisgarh	3
Gujarat	6
Haryana	1
Jharkhand	4
Karnataka	1
Madhya Pradesh	4
Maharashtra	8
Odisha	3
Punjab	1
Rajasthan	1
Tamil Nadu	4
Telangana	2
Uttar Pradesh	9
West Bengal	7

Source: Central Electricity Authority, 2020

Chapter 5
Iron & Steel



India's focus on robust manufacturing-led growth, along with the 'Make in India' vision has made the steel sector one of the most significant ones for the country's economy. In terms of crude steel production, India is already the second largest player in the world after China. The Government further envisages increasing the crude steel capacity to 300 million metric tonnes (MMT) by 2030, which is nearly three times the current capacity. This is based on competitive advantages that India has for steel production: domestic availability of high-grade iron ore and non-coking coal (two important raw materials), a rapidly growing market for steel, and competitive labour costs.[1]

However, the contribution of the iron and steel sector to global GHG emission is a growing concern. The sector's high reliance on coal, which is 74% of its energy inputs, contributes to significant CO_2 emissions. In 2019, the sector accounted for 2.6 Gt of direct CO_2 emissions globally, which is about one-fourth of total industrial CO_2 emissions and 7% of total energy sector emissions (including process emissions).[2]

India's iron and steel industry is resource and energy intensive, a major share of which is coal. In 2019-20, steel, along with the sponge iron sector, accounted for over 10% of the total coal consumption (See section on coal mining). At the same time, the sector consumes about 70 Mtoe of energy per year and coal accounts for 85% of the energy input. In 2019, direct emission of the sector was about 250 Mt CO_2, which is nearly 10% of the country's total energy system CO_2 emission.[3]

In such a scenario, the transition of the iron and steel sector will be extremely important for a system-wide transition in India to reduce GHG emission. This, in turn, will require a consideration for transition of the workforce and regions where the sector constitute an important component of the economy.

1. Spatial distribution

India currently has 2,531 iron and steel units, which include large integrated steel plants, mini steel mills, sponge iron plants and secondary producers like rolling mills and other ancillary industries (Table 1).[4]

Table 1: Number of iron and steel plants in India

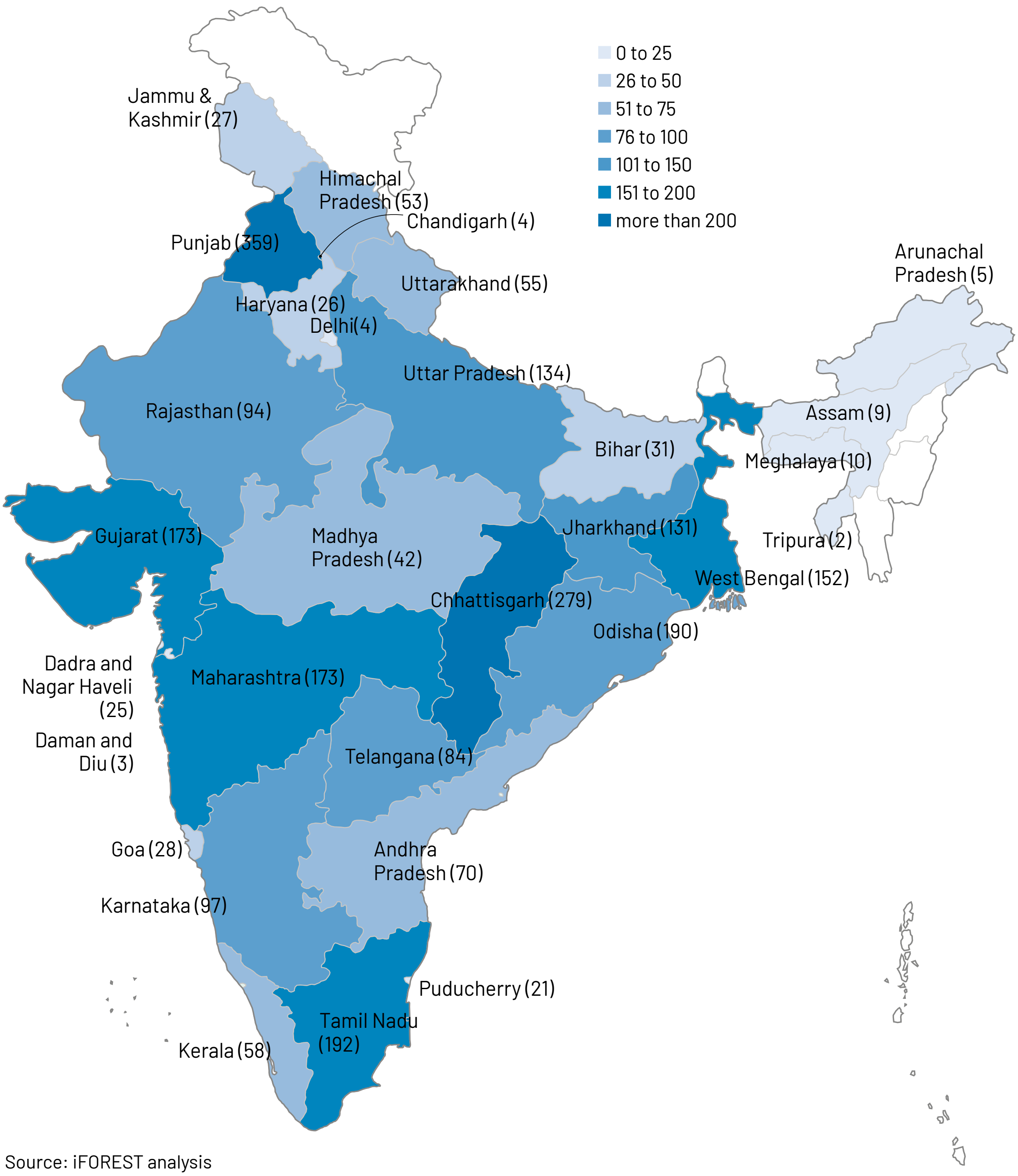
Segment	No. of units	Annual capacity (MMT)
Pellets	39	81.14
Sponge iron	285	47.85
Blast furnace	57	79.57
Crude steel		
Basic oxygen furnace (BOF)	17	57.30
Electric arc furnace	39	40.51
Induction furnace	858	44.50
Total crude steel	914	142.30
Finished Steel		
Re-rolling	1020	79.60
HR Products	23	54.38
CR Products	68	26.35
GP/GC Sheets	28	9.61
Colour Coated Products	17	2.82
Tinplate	4	0.84
Pipes	76	9.43
Total finished steel	**1,236**	**183.03**

Source: Joint Plant Committee, Ministry of Steel, 2020

Most of the units are concentrated in five states: Chhattisgarh, Odisha, Jharkhand, Karnataka, and Maharashtra. In 2019-20, these five states have over one-third (870) of the units (Map 1). Among them, Chhattisgarh has the maximum number of plants (279), followed by Odisha (190), Maharashtra (173), Jharkhand (131), and Karnataka (97).[5]

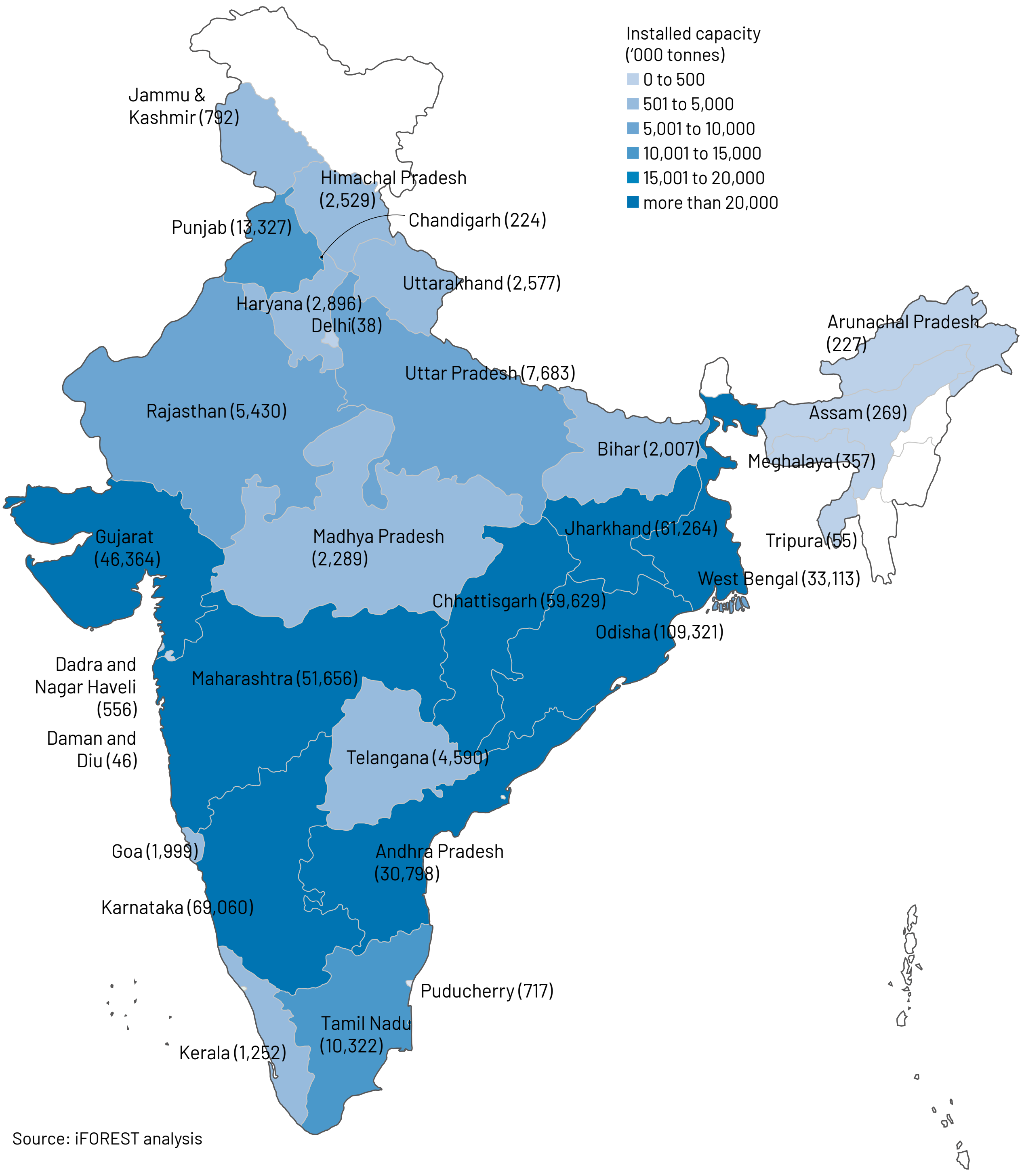
With respect to total installed capacity, Odisha tops the chart (over 109 MMT capacity) given high access to two of the necessary raw materials, iron ore and coal. Similarly, Chhattisgarh, Jharkhand, Karnataka and Maharashtra also have very high capacity (over 50 MMT each), given their access to both of these resources (Map 2).

Map 1: State-wise distribution of steel plants (number)



Source: iFOREST analysis

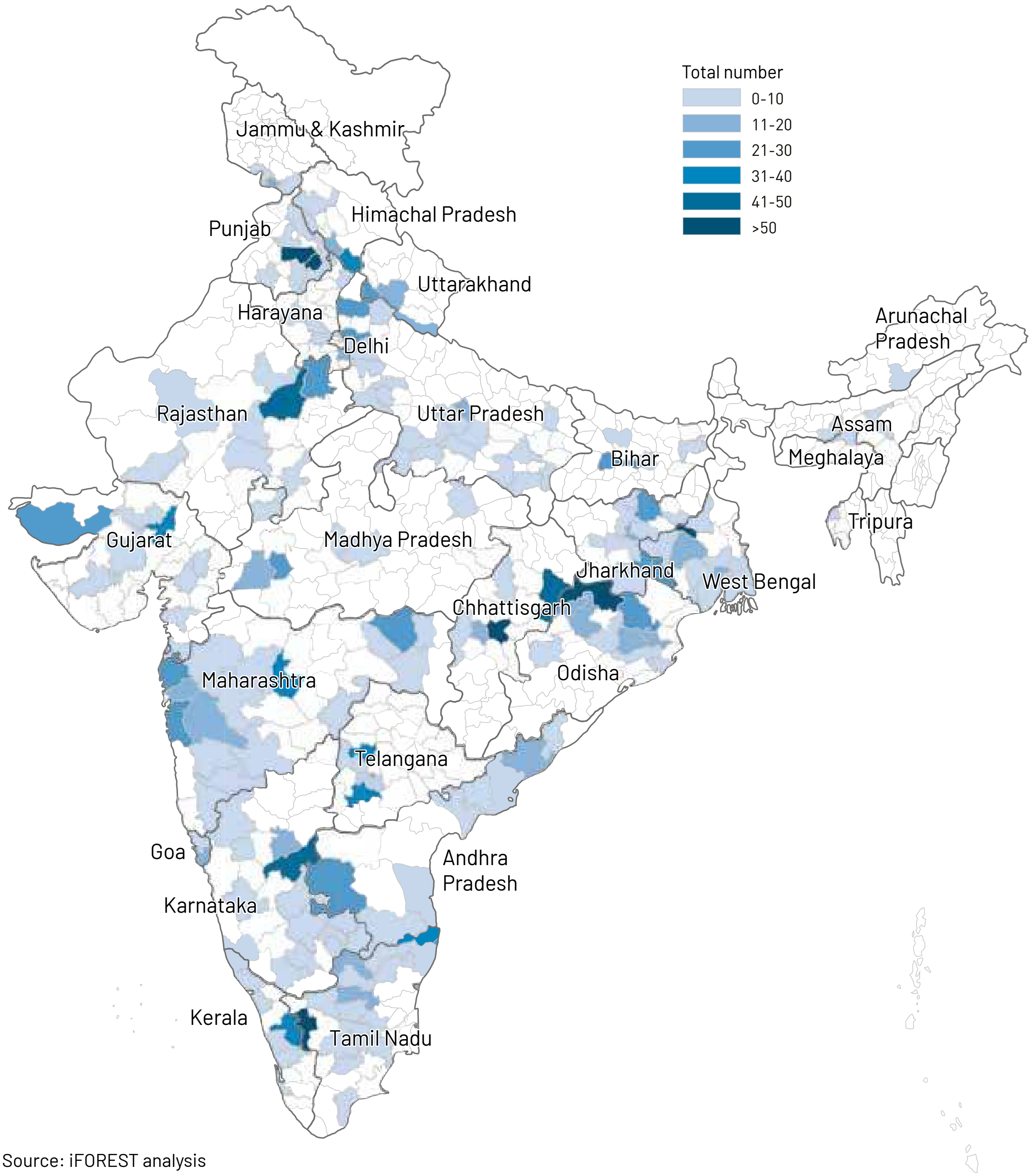
Map 2: State-wise distribution of steel plants (capacity)



Source: iFOREST analysis

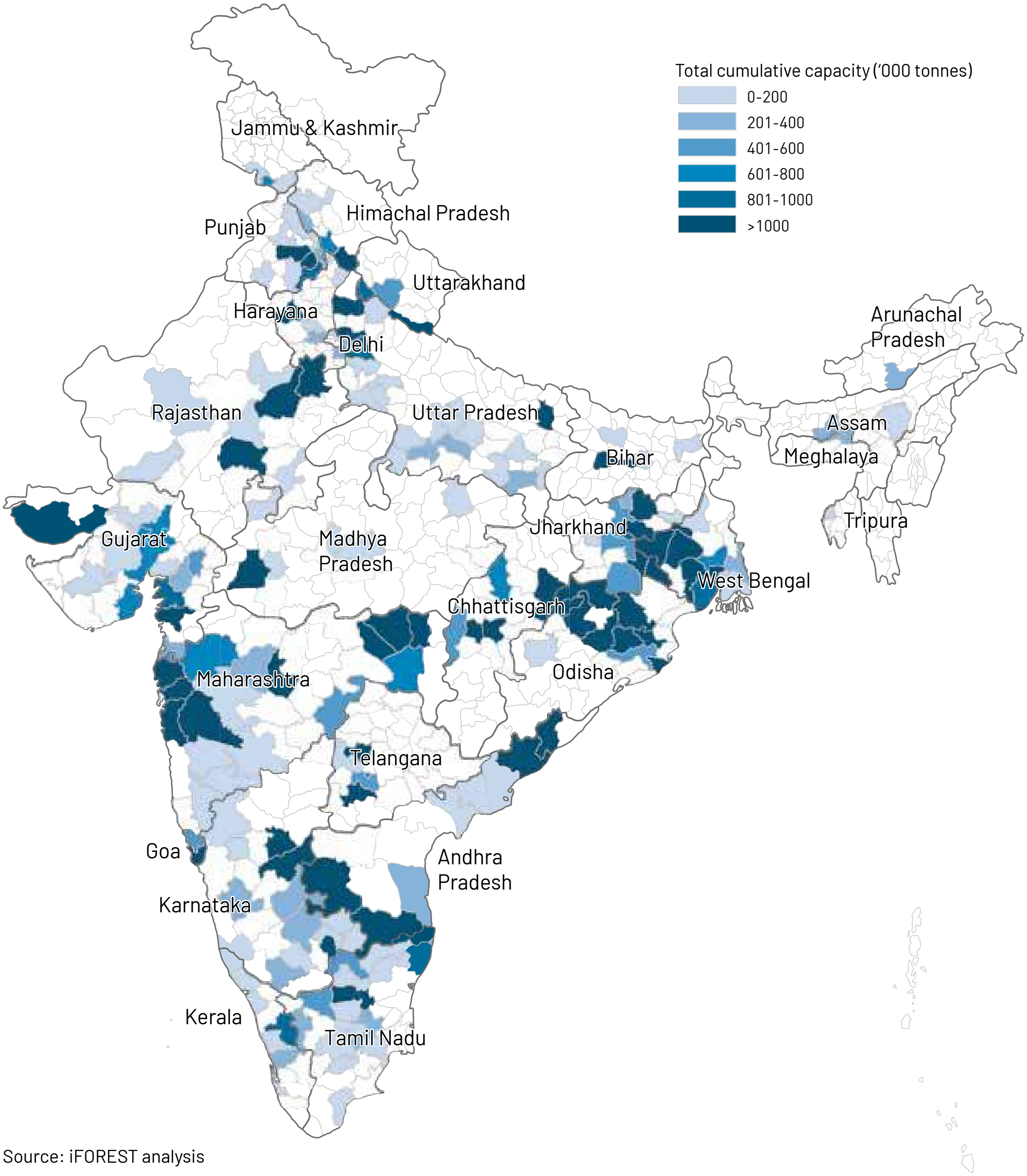
A district-wise analysis further brings out the precise geographical distribution of India's steel production. In terms of number of plants, the iron and steel sector is highly dispersed (Map 3 and 4). There are 30 districts having more than 25 plants each. Some of these districts such as Raipur in Chhattisgarh and Fatehgarh Sahib in Punjab have more than 200 plants each.

Map 3: District-wise distribution of iron and steel plants (number)



Source: iFOREST analysis

Map 4: District-wise distribution of iron and steel plants (capacity)



Source: iFOREST analysis

However, crude steel production is highly concentrated. There are just 20 districts that produce more than 1 million metric tonnes (MMT) of crude steel annually (Table 2). These districts, together, account for 77% of India's crude steel making capacity. From a just transition perspective, these districts are more important as major energy transition is required in the production of crude steel.

Table 2: Top steel producing districts of India			
State	**District**	**No. of crude steel plants**	**Total capacity (MMT)**
Andhra Pradesh	Visakhapatnam	2	6.3
Chhattisgarh	Raigarh	17	6.3
	Raipur	53	5.9
Gujarat	Surat	1	10
	Kutch	7	1.2
Jharkhand	East Singhbhum	7	10.2
	Bokaro	4	6.5
	Seraikela Kharsawan	14	2
Karnataka	Bellary	6	13.8
Maharashtra	Nagpur	6	5.2
	Wardha	2	1.4
Odisha	Durg	6	6.3
	Dhenkanal	4	5.6
	Sundargarh	28	5.2
	Angul	1	5
	Jajpur	4	4.8
	Sambalpur	3	3.5
Tamil nadu	Salem	9	1.3
	Tiruvallur	15	1.2
West Bengal	Paschim Bardhaman	26	8.1
Total		**215**	**109.8**

Source: Joint Plant Committee, Ministry of Steel, 2020

2. Production and import

In 2019, India produced over 111 MMT of crude steel, which is about 78% of the installed capacity (142.3 MMT). Finished steel production during the same period was about 104 MMT, and for sponge iron, it was nearly 37 MMT (Table 3). The coal-based route accounted for about 82% of total sponge iron production (37.10 MMT)

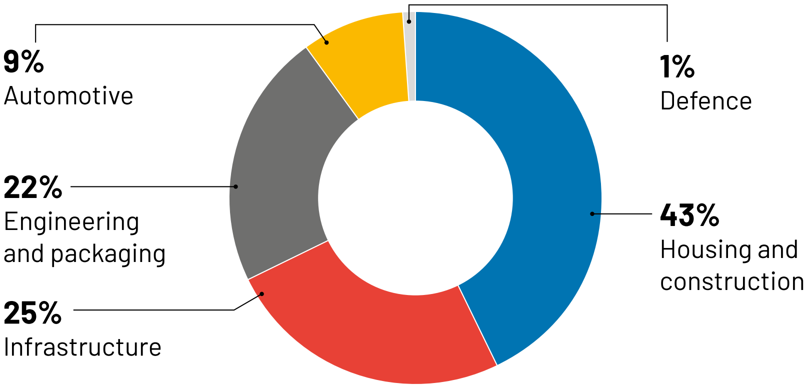
Table 3: Crude and finished (alloy + non-alloy) steel production (2019-20)			
Category	**Production (MMT)**	**Import (MMT)**	**Export (MMT)**
Crude steel	111.34	-	-
Sponge iron	36.8	-	-
Finished steel	102.62	7.44	8.21

Source: Ministry of Steel, 2021

3. Consumption

The overall steel demand has been showing a steady growth over the past seven years at a CAGR of 5.3%. In 2019-20, India's total steel consumption was 100 MMT, driven largely by the demand from the housing and construction sector, which accounted for 43% of the total consumption. The other key sectors are infrastructure, engineering and packaging, and automotive (Figure 1).[6]

Figure 1: Sector-wise steel consumption



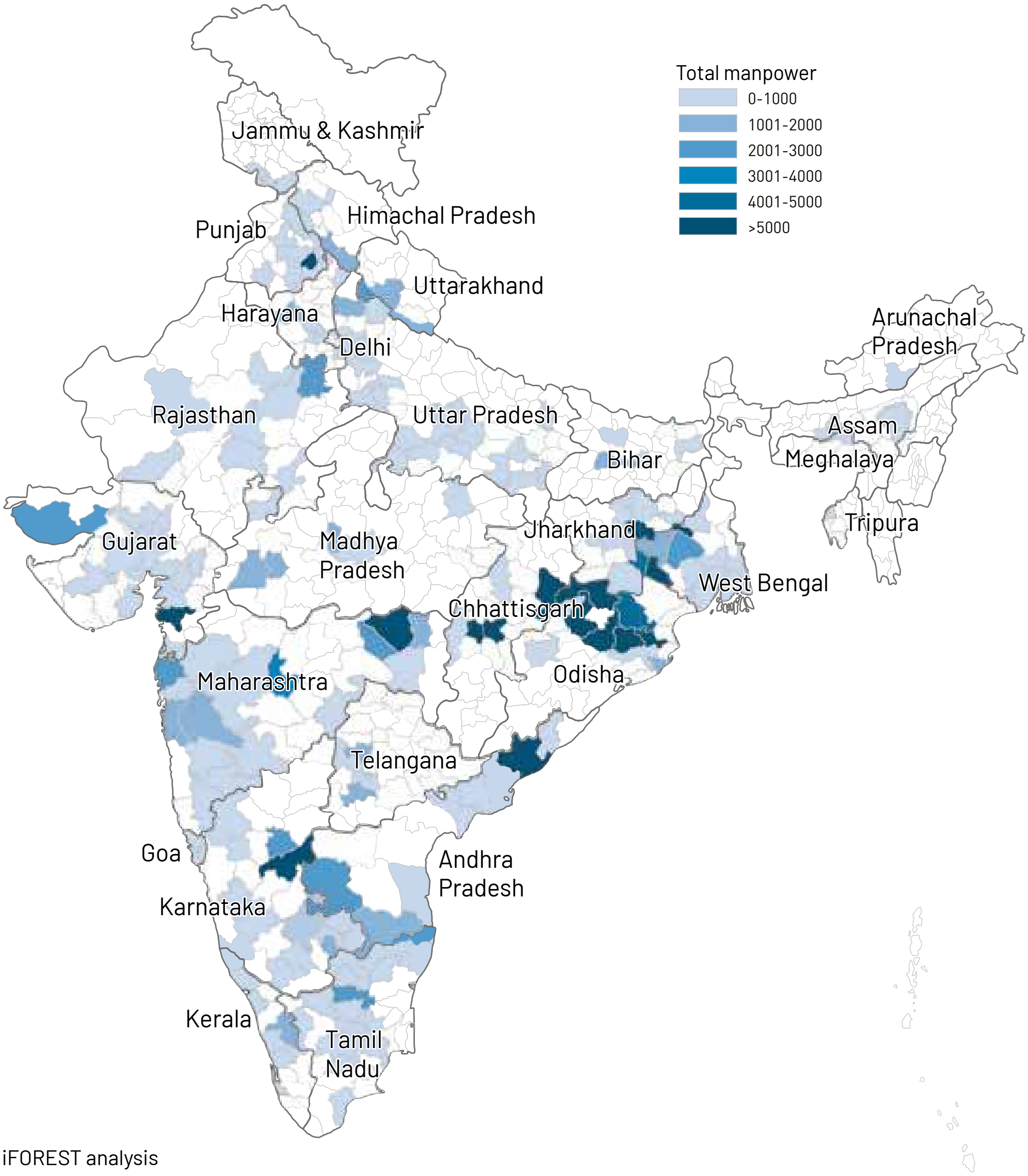
Source: Ministry of Steel, 2021

4. Employment

While an overall employment scenario of the steel sector is not available, an attempt has been made to estimate this by developing employment factors for various segments of the iron and steel value chain. For large units, an employment factor approach has been followed by analysing manpower of major steel producers, including Steel Authority of India Limited (SAIL), Rashtriya Ispat Nigam Limited (RINL), Tata Steel Limited and JSW Steel Limited.

The overall formal employment in the iron and steel industry can be estimated to be about 0.34 million as of 2019-20.[7] More than 75% (0.26 million) of this is concentrated in the top 25 steel districts (Map 5). However, considering the high proportion of informality in the manufacturing sector (about 88%),[8] it is evident that the overall employment (formal and informal) is far higher. It has further been estimated that about 2 million people are indirectly employed by the steel sector.[9]

Map 5: District-wise distribution of formal employment in iron and steel industry



Source: iFOREST analysis

5. Future opportunities and just transition scenario

The projected growth of the steel sector under a business-as-usual scenario is strongly correlated to growth of energy demand, which is largely reliant on coal (as discussed earlier). However, to reduce India's overall CO_2 emission, the energy- and resource-intensive nature of the steel industry will have to change.

The low carbon pathway for the sector will not be a case of shutting down steel units, but a change in technology. Also grandfathering (old rules apply to existing situations and new rules apply to future cases) will not be an option for the steel sector, unlike some of the old thermal power plants (TPPs), as the steel-producing units in India are through with a little more than one-third of their typical lifetime, which is around 40 years on average.[10]

For the iron and steel sector, therefore, the need is for a rapid transformation of the production fleet to reduce coal dependence and support low-emission technologies and infrastructure. The good news is that some of the technologies to reduce the sector's emission footprint are at hand. They are being used by some countries already. Further, there are other technologies, which will be available in the next 10-15 years.[11]

The technologies that can lead to reduced emission in the iron and steel production processes include, carbon capture, utilisation and storage (CCUS), hydrogen-based technologies, direct electrification, and bioenergy. A synopsis of these technologies and their applications in various production processes is provided below (Table 4). The evaluation provides an understanding on the availability of the key technologies with respect to production processes, the Technology Readiness Level (TRL)[12], the timeframe of availability, as well as effectiveness in emission reduction.

For India, it is expected that within the next 10-15 years, some of the more radical decarbonization technologies, which are currently being demonstrated, would be commercially available. This particularly includes hydrogen-based production, which involves the substitution of coal or natural gas as a reducing agent with hydrogen. Supported by India's RE advancements, if hydrogen is produced from emissions-free electricity, the total emissions from the iron and steel industry can be reduced by 94%. It is also further estimated that if hydrogen can be delivered at a cost of 2.5-3.5 US$/kg, it will be cost competitive with the blast furnace and basic oxygen furnace (BF-BOF) route of steel production.[13]

In the immediate future, the sector can maximise its operational efficiency by investing in best available technologies (BAT). For instance, around 40% of blast furnaces in India are currently equipped with top-pressure recovery turbines (TRTs), and over 30% of coke ovens are equipped with coke dry quenching (CDQ), two examples of BAT. Widespread adoption of these technologies, along with efforts towards achieving material efficiency, can contribute to considerable emission reductions.[14]

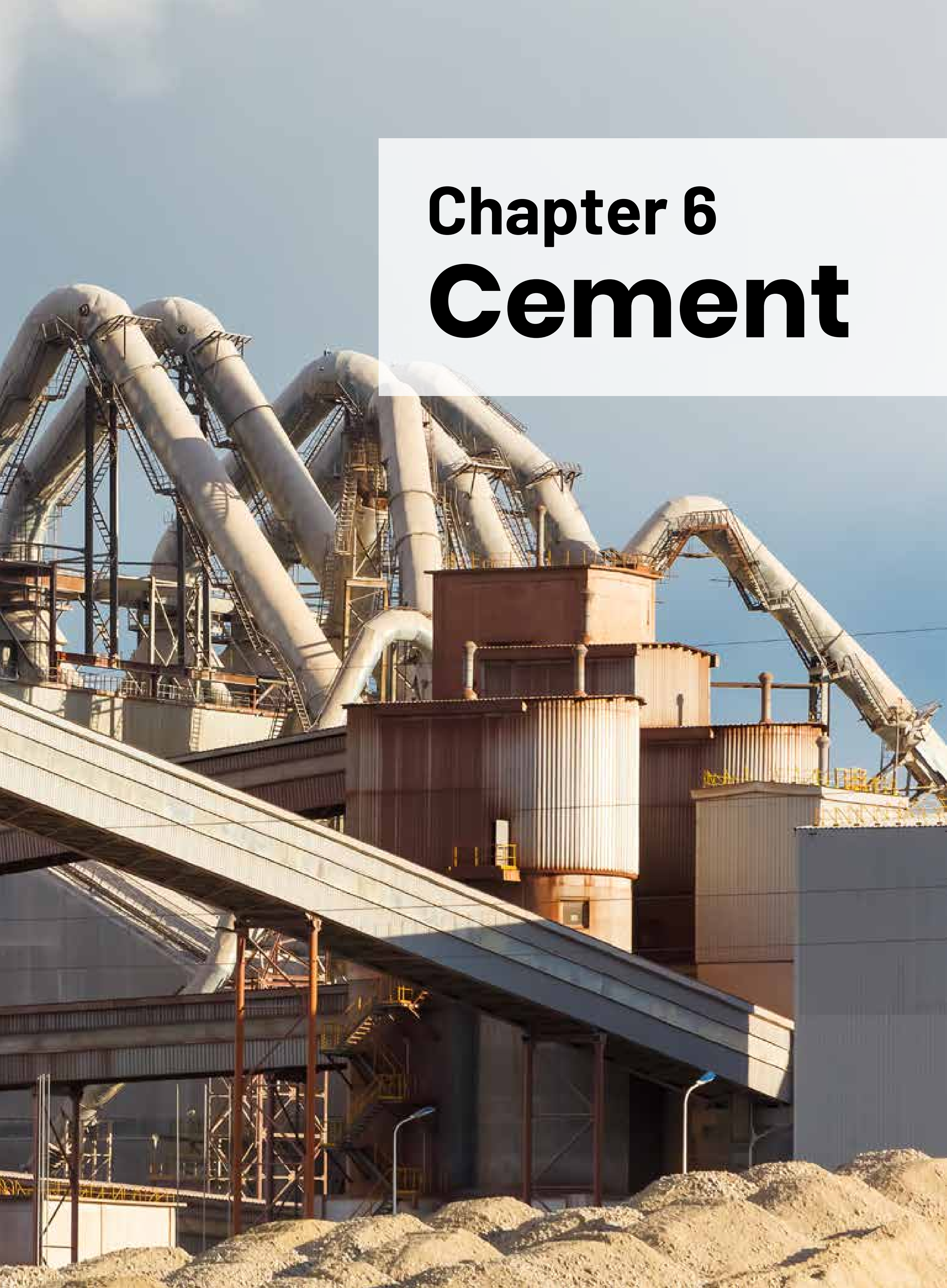
A just transition for the workers associated with the iron and steel sector will primarily involve 'reskilling and retraining'. The maximum proportion of this will be required in units using the BF-BOF route and the sponge iron units. As evident from the spatial distribution, the particular focus of this will be the states of Odisha, Chhattisgarh, and Jharkhand, which have over 40% share of the total manpower.

Table 4: Technological readiness of steel sector transition

Technology	Process	TRL	Year available	Potential for emission reduction
CCUS	Blast furnace: Off-gas hydrogen enrichment and/or CO_2 removal for use or storage	5	2030	Very high
	Blast furnace: Converting off-gases to fuels	8	At present	Medium
	Blast furnace: Converting off-gases to chemicals	7	2025	Medium
	DRI: Natural gas-based with CO_2 capture	9	Today	Very high
	Smelting reduction	7	2028	Very high
Hydrogen	Blast furnace: Electrolytic H_2 blending	7	2025	Medium
	DRI: Natural gas-based with high levels of electrolytic H_2 blending	7	2030	High
	DRI: Based solely on electrolytic H_2	5	2030	Very high
	Ancillary processes:H_2 for high temperature heat	5	2025	High
Direct electrification	Electrolysis: Low temperature	4	-	Medium
	Electrolysis: High temperature molten oxide	4	-	Medium
Bioenergy	Blast furnace: Torrefied Biomass	7	2025	Medium
	Blast furnace: Charcoal	10	At present	Medium

Source: Adopted from International Energy Agency, 2020

Chapter 6
Cement



India is the second largest cement producer in the world, accounting for about 8% of the world's cement production.[1] Given the sustained growth of construction activities, coupled with ambitious schemes of the Government that are in various stages of planning and implementation,[2] the demand and consumption of cement will increase significantly in the coming decades. As per latest estimates of industry association and the Government, by 2025, the demand for cement per year will be about 550-600 MMT.[3] By 2050, cement production in the country will reach 1.36 billion tonnes annually.[4]

The growing demand and increase in cement production will be accompanied by increasing carbon footprint in the coming years under a business-as-usual (BAU) scenario. On a global scale, the cement sector is the third-largest industrial energy consumer and is responsible for 7% of industrial energy use. It is also the second largest industrial emitter of CO_2, with about 7% share of global emissions.[5]

While India is considered one of the most energy-efficient countries when it comes to cement manufacturing, the emission footprint is still significant. The sector consumes about 26 million tonnes of oil equivalent (Mtoe) of energy per year.[6] In 2019, the sector emitted about 144 Mt CO_2 —about 6% of the country's emissions.[7]

Considering the growing demand for cement in construction and infrastructure (which is aligned to India's growth ambition), it will be important for the sector to reduce its carbon footprint significantly. To echo what was enshrined in the Paris Agreement 2015, the sector must also consider "the imperatives of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities."[8]

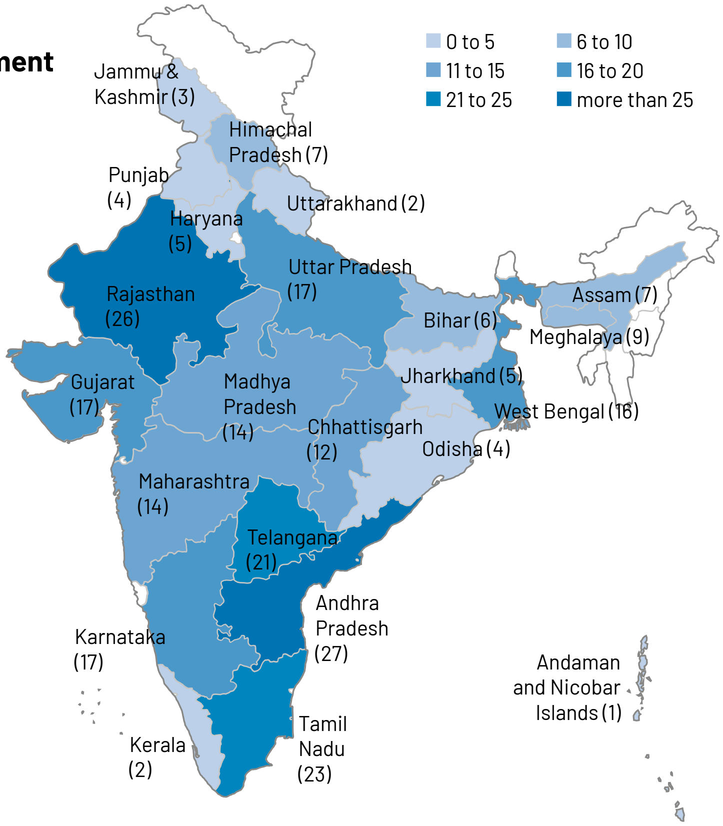
1. Spatial Distribution

India currently has 259 operational cement plants (large units), which include integrated cement plants as well as clinker producing units. Besides, there are more than 350 mini cement plants with an estimated production capacity of about 11.1 MMT.[9] About 99% of production capacity lies with the private sector.

While there are 23 cement-producing states in the country, most of the large units are concentrated in eight states: Rajasthan, Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, Gujarat, Maharashtra, and Madhya Pradesh. Over 61% of the units are found in these eight states as well. Among them Rajasthan (26) and Andhra Pradesh (27) have the maximum numbers (Map 1).

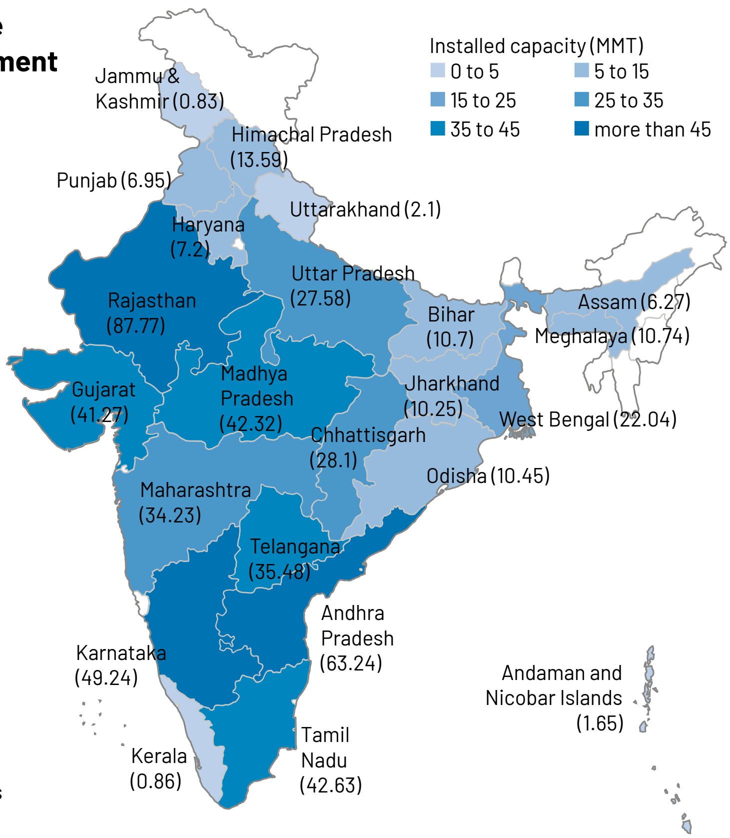
These states collectively account for over 71% of the country's total production capacity (Map 2). In 2019-20, Rajasthan topped the chart with a production capacity of nearly 88 MMT per year. However, region wise, the southern part of India has the maximum capacity, including the states of Andhra Pradesh (over 63 MMT), Telangana (over 35 MMT), Karnataka (over 49 MMT) and Tamil Nadu (over 43 MMT).[10]

Map 1: State-wise distribution of cement plants (number)



Source: iFOREST analysis

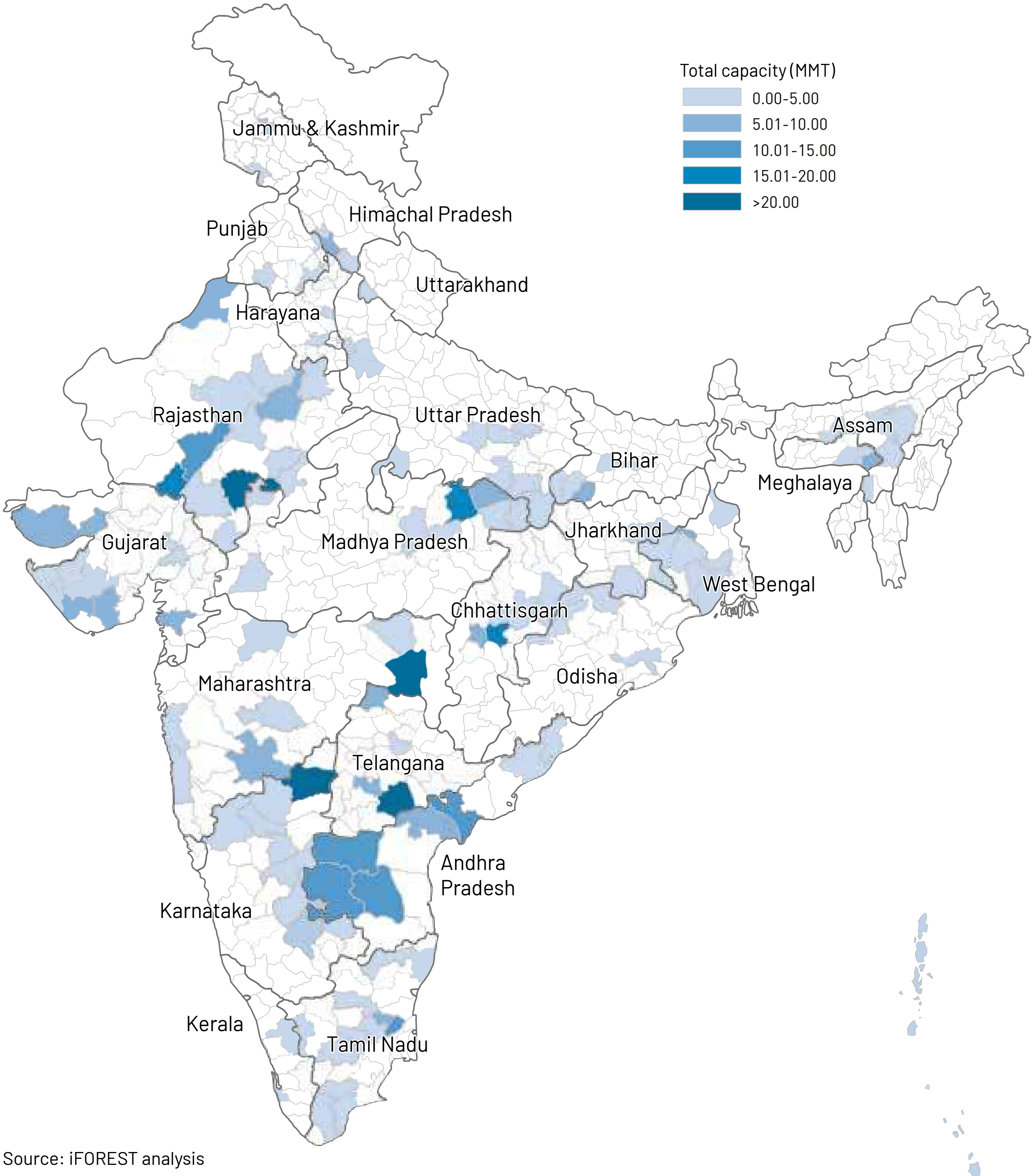
Map 2: State-wise distribution of cement plants (capacity)



Source: iFOREST analysis

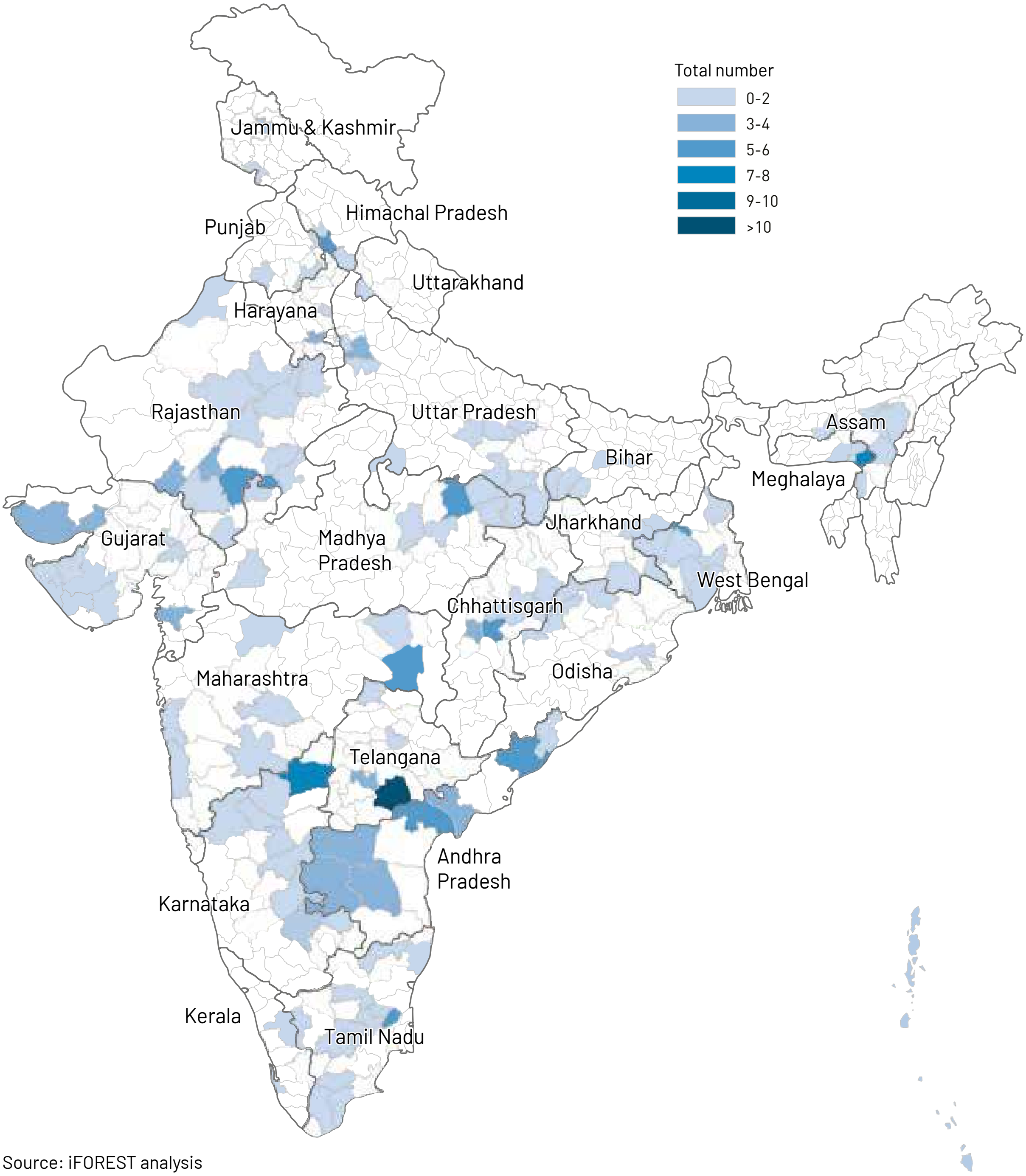
The district-wise analysis shows that there are a total of 130 cement-producing districts in the country, with a higher concentration in the Southern and Western parts of India (Map 3 and Map 4). However, only 25 districts account for over 58% of the production capacity (Table 1). Gulbarga district of Karnataka has the highest capacity. It has eight plants with a combined capacity of about 33.6 MMT.

Map 3: District-wise distribution of cement plants (capacity)



Source: iFOREST analysis

Map 4: District-wise distribution of cement plants (number)



Source: iFOREST analysis

Table 1: Top 25 cement districts			
State	**District**	**No. of plants**	**Installed capacity (MMT)**
Andhra Pradesh	Anantapur	4	14.2
	Guntur	5	6.1
	Kadapa	4	13.76
	Krishna	4	13.16
	Kurnool	4	11.77
Bihar	Aurangabad	2	5.6
Chhattisgarh	Durg	3	7.3
	Raipur	6	15.15
Gujarat	Amreli	2	7.85
	Junagadh	2	6.9
	Kutch	3	7.5
	Surat	4	9.66
Himachal Pradesh	Solan	5	8.94
Karnataka	Gulbarga	8	33.58
Madhya Pradesh	Satna	6	19.5
Maharashtra	Chandrapur	5	19.95
Meghalaya	East Jaintia Hills	7	8.56
Rajasthan	Chittorgarh	6	28.4
	Pali	4	12.88
	Sirohi	3	18.4
Tamil Nadu	Ariyalur	5	12.56
	Perambalur	2	6.55
Telangana	Nalgonda	15	22.5
	Ranga Reddy	3	5.9
West Bengal	Paschim Bardhaman	6	6.69

Source: Data computed from Indian Bureau of Mines, 2020

2. Production

In 2019-20, India produced about 334.37 MMT of cement.[11] There is a significant difference between installed and production capacity due to low utilisation of capacity, which has reduced from 83% to 60% since 2010. The top 20 cement companies in India account for almost 70% of the total cement produced.[12]

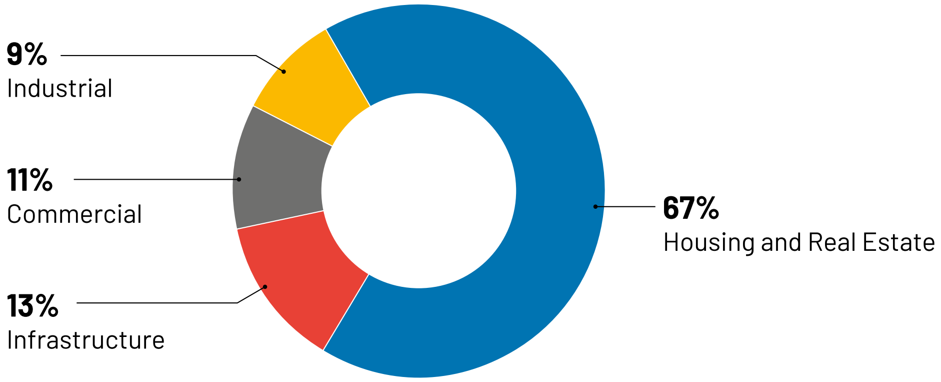
India is largely self-sufficient in cement. The country remains a net exporter of cement; it exported 5.8 MMT of cement in 2019, worth ₹ 20.3 billion. The import was only about 2.3 MMT, 50% of which was Portland grey cement.[13]

3. Consumption

India's cement consumption has been steadily growing over the last decade due to demand from construction activities. Between 2012 to 2019, cement consumption increased from 240 MMT to 338 MMT.[14]

The demand of cement is primarily driven by the growth in housing and real estate sectors, which collectively account for about 67% of the total consumption. This is followed by infrastructure, commercial, and other industrial sectors.[15] (Figure 1)

Figure 1: Sector-wise cement consumption



Source: WBCSD, 2019

4. Employment

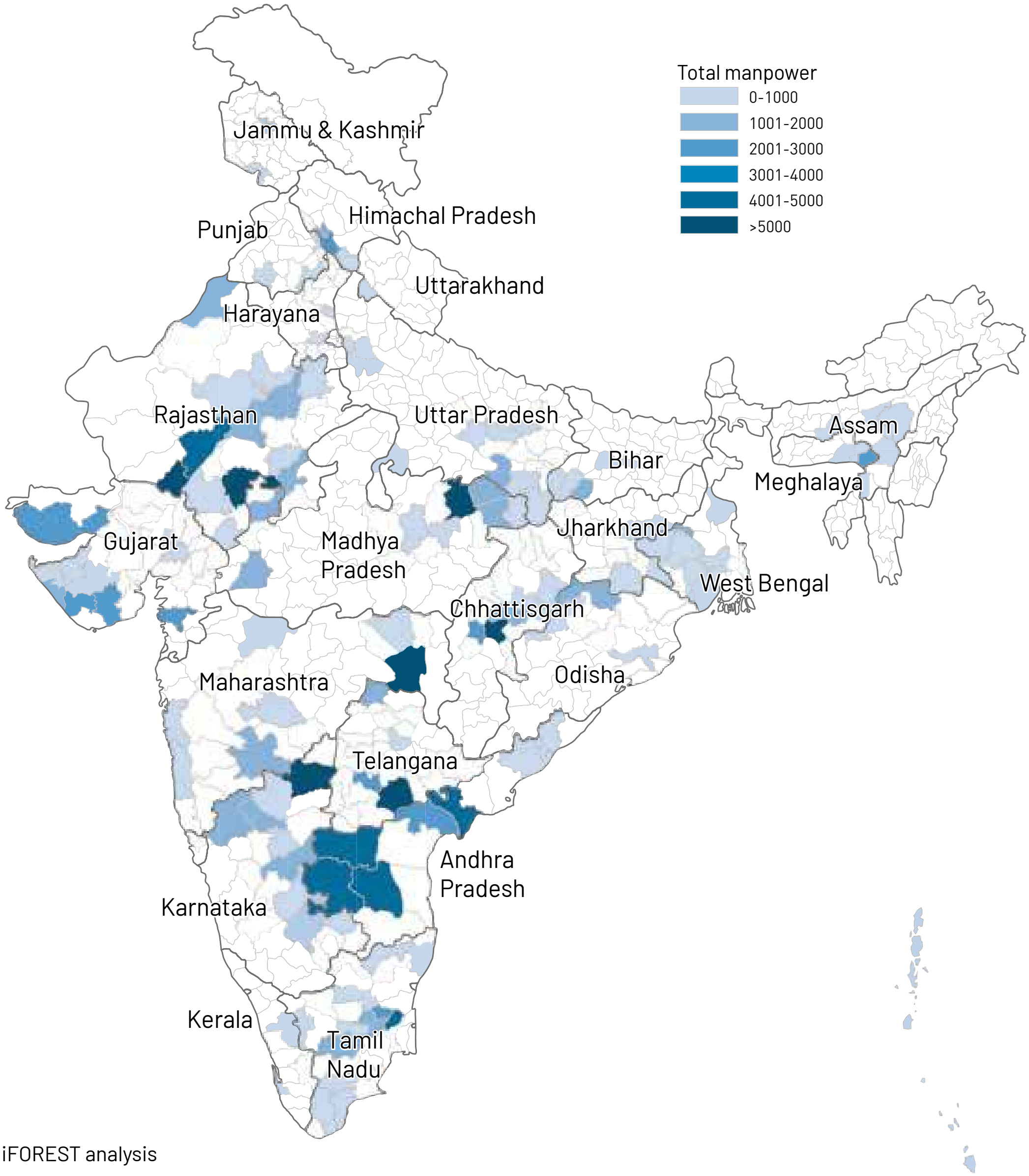
While there is no current estimate available on overall manpower directly employed by the cement sector, the estimation has been arrived at by analysing the manpower requirement separately for major integrated cement plants and grinding units, and then considering an employment factor approach for both separately. The estimated employment, however, is commensurate with the earlier estimates of the Government of India.[16]

The cement companies (operating large plants), currently, provide direct employment to about 0.17 million people. Over 65% (over 0.1 million) of this is concentrated in the top 25 cement districts (Map 5). The informal employment in the cement plants is estimated to be 1.3 million, using the formal-informal ratio derived from National Sample Survey (NSS).[17] Overall, large cement factories employ about 1.5 million people.

As a key driver of many manufacturing and construction activities, the sector also has significant implications for downstream employment. It is estimated that the sector employs about 20,000 people downstream for every million tonnes of cement produced.[18]

Besides, the 350 plus mini cement plants are a significant source of local employment. While estimates are not available, this is clear from the intention with which these were set up in the late 1970s. As envisioned by the Government of India, these plants are supposed to augment local cement production, but also intended for developing small entrepreneurs, generating local employment, and boosting the local economy.[19]

Map 5: District-wise employment distribution in cement industry



Source: iFOREST analysis

5. Future opportunities and just transition scenario

The cement sector has been considered one of the most energy-efficient ones among the major economic sectors. However, fossil fuels (particularly coal) continue to be the major energy supplier for cement production, a large amount of which is consumed during the calcination process (clinker production).[20]

There are a number of propositions to reduce CO_2 emissions from the cement industry, and increase its production efficiency. Use of alternative fuels (such as industrial and municipal waste) in producing clinker is one of the options.[21] Besides, there are considerations for the use of Supplementary Cementitious Materials (SCM), such as geopolymer/alkali activated cement, calcium sulfoaluminate (CSA) cement, magnesia binder, celitement, etc., that will help reduce the use of clinker for cement production, and thereby reduce the overall requirement of coal.[22]

There are also evaluations that are being done in the Indian context. Some of the technological opportunities that have been identified, include the use of waste heat recovery systems and carbon capture, utilisation and storage (CCUS),[23] A synopsis of these technologies and their application in various production processes is provided below (Table 2).

Table 2: Technological opportunities in cement sector

Energy saving opportunities	Technology readiness level	Payback period
Waste heat recovery	Fully commercial	5 to under 8 years
Co-processing and pre-processing platform for increased alternative fuel utilisation	Fully commercial	Over 12 years
Carbon capture through algal growth	First of a kind	-
Oxy-fuel combustion technology	Demonstration level	-

Source: Adopted from Bureau of Energy Efficiency, 2018

With respect to just transition, the cement sector will not see a downsizing in the number of production facilities in the coming two decades in India. The sector will keep reducing its carbon footprint by using alternate fuels and raw materials, and by improving efficiency. But in the long term, the cement sector will have to rely on CCUS to survive. The other option is to develop alternative cementitious material without carbon emissions. In essence, technology transfer and capacity building are a key for the sector to keep innovating and delivering low- carbon products.

Chapter 7

Road Transport

The transport sector is the largest oil consumer in India, accounting for about 50% of the total oil consumption (237.2 MMT) in 2019-20 (Table 1). High volume of oil consumption makes it one of the largest contributors to GHG emissions in the country as well.

Within the transport sector, road transport accounts for about 90% of the total GHG emissions.[1] In fact, road transport is the second largest source of GHG emissions in India, accounting for about 10% of the total emissions.[2] Most of it is accounted for by freight vehicles (trucks), passenger cars, two-wheelers (2Ws), and three-wheelers (3Ws) (Table 2).

Table1: Fuel consumption by transport sector

Sector	Consumption (MMT)	Share of total consumption (%)
Transport	44.86	18.92
Resellers and retail*	71.1	29.97
Total	**115.9**	**48.9**

Source: NITI Aayog Energy Dashboard, 2021; * Reseller and retail largely cover the transport sector

Table2: GHG emissions from road transport

Emission components	GHG emissions as share of India total (%)
Trucks	4.4
2Ws and 3Ws	2.0
Passenger cars	2.0
Other road transport	1.4

Source: iFOREST estimates

1. Current status and demand

The oil demand for road transport is primarily driven by road freight activity. Since 2000, India's freight activity has grown by four times, and there has been a 13-fold increase in the stock of heavy freight trucks.[3] India is currently the fifth largest country in the world with respect to commercial vehicle sales (0.85 million, as per sales records of 2019), after the USA, China, Canada, and Japan.[4]

India is also the fifth largest in the world with respect to passenger car sales, after China, USA, Japan, and Germany. In 2019, nearly three million passenger cars were sold.[5] Besides, the number of 2Ws and 3Ws—which have a large share in the total fleet of vehicles—is five times larger than passenger cars.[6]

However, in 2020, the sale of automobiles has experienced a significant dip, particularly in the sales of 2Ws and 3Ws (Table 3). This is due to the ongoing COVID-19 pandemic, which affected consumer demand. However, a rapid comeback is expected by 2023 (getting back to 2019 levels).[7] In the long run, it is projected that under a business-as-usual scenario and steady recovery from COVID-19, there will be an addition of 170 million passenger cars and 25 million trucks to the vehicle stock.[8]

Table 3: Domestic automobile sales					
Category	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**
Passenger cars	2,025,097	2,103,847	2,174,024	2,218,489	1,695,441
Utility vehicles	586,576	761,998	922,322	941,474	946,010
Vans	177,535	181,737	192,235	217,426	132,124
Total Passenger Vehicles	**2,789,208**	**3,047,582**	**3,288,581**	**3,377,389**	**2,773,575**
Total 3Ws	**538,208**	**5,11,879**	**635,698**	**701,005**	**636,569**
Scooters	5,031,678	5,604,673	6,719,909	6,701,430	5,566,036
Motorcycles	10,700,406	11,094,547	12,620,690	13,598,190	11,214,640
Mopeds	723,767	890,518	859,518	880,227	636,940
Total 2Ws	**16,455,851**	**17,589,738**	**20,200,117**	**21,179,847**	**17,417,616**
MCVs and HCVs	302,397	302,567	340,781	390,732	224,806
LCVs	383,307	411,515	516,135	616,579	492,882
Total commercial vehicles	**685,704**	**714,082**	**856,916**	**1,007,311**	**717,688**
Quadricycle	-	-	-	627	942
Total	**20,468,971**	**21,863,281**	**24,981,312**	**26,266,179**	**21,546,390**

Source: Society of Indian Automobile Manufacturers, Annual Report 2020-21

2. Automobile production, component manufacturing and distribution

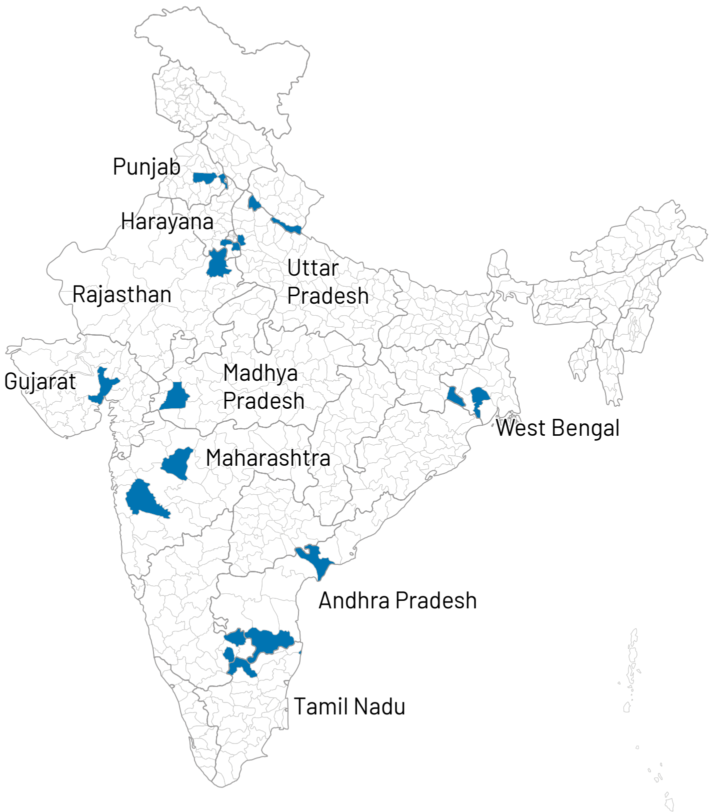
The automobile industry in India produced over 23 million vehicles in 2019-20, which included passenger vehicles, commercial vehicles, 2Ws and 3Ws, and quadricycles. Among these, the highest production share is of 2Ws, which is nearly 80% of the total production (Table 4).

Table 4: Domestic automobile production					
Category	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**
Passenger Cars	2,565,970	2,711,911	2,746,658	2,711,160	2,175,242
Utility Vehicles	717,809	909,555	1,093,346	1,099,780	1,124,973
Vans	181,266	180,204	180,263	217,531	133,798
Total Passenger Vehicles	**3,465,045**	**3,801,670**	**4,020,267**	**4,028,471**	**3,434,013**
Three Wheelers	**93,4104**	**783,721**	**1,022,181**	**1,268,833**	**1,133,858**
Scooters	5,276,138	5,926,499	7,117,795	7,095,164	6,027,198
Motorcycles	12,816,203	13,088,208	15,167,481	16,499,424	14,359,418
Mopeds	737,886	919,032	869,562	905,189	649,678
Total Two Wheelers	**18,830,227**	**19,933,739**	**23,154,838**	**24,499,777**	**21,036,294**
MCVs and HCVs	341,287	342,761	344,592	444,356	233,979
LCVs	445,405	467,492	550,856	668,049	518,043
Total Commercial Vehicles	**786,692**	**810,253**	**895,448**	**1,112,405**	**752,022**
Quadricycles	531	1,584	1,713	5,388	6,095
Total	**2,4016,599**	**25,330,967**	**29,094,447**	**30,914,874**	**26,362,282**

Source: Society of Indian Automobile Manufacturers, Annual Report 2020-21

As a global hub of cost-effective and scalable engineering, India's automobile manufacturing industry remains a successful one. While original equipment manufacturers (OEMs) and component manufacturers are spread across various states in India (Map 1), there are primarily three dominating automobile clusters: Mumbai-Pune-Nasik-Aurangabad in the West, Chennai-Bengaluru-Hosur in the South, and Delhi-Gurugram-Faridabad in the North.[9]

Map 1: Key Automobile OEM and component manufacturing districts



Source: iFOREST analysis

3. Employment

While there are many estimates on the number of people employed by the automobile sector, it can be reasonably assumed that the sector employs in excess of 12 million people (Table 5). Auto component manufacturers (ACMs) and service centres—the two most critical sub-sectors which are likely to be impacted by the energy transition—employ 70% of the people.

Table 5: Employment in the automobile sector

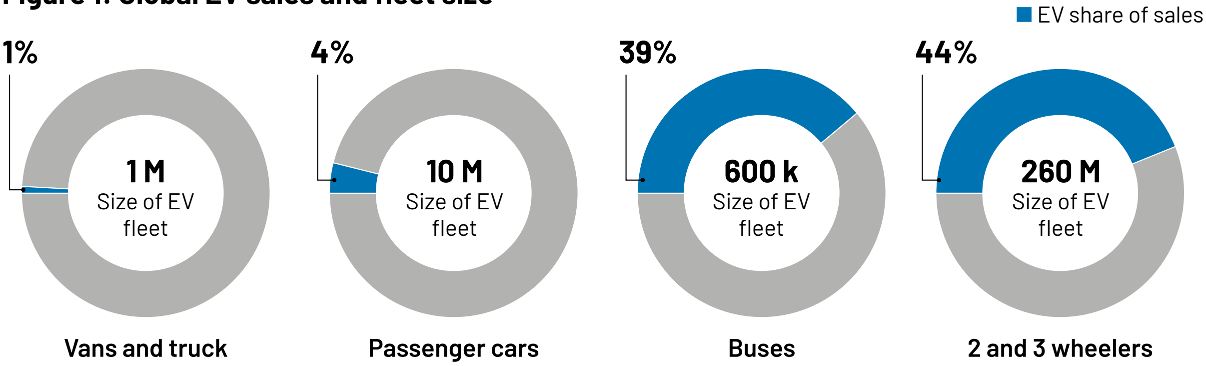
Sector	Employment (in million)	
	2017	2022 (Projected)
OEM	2.04	2.23
ACM	5.99	7.26
Service centers	3.10	3.44
Dealerships	1.68	1.95
Total	**12.81**	**14.88**

Source: National Skill Development Council, 2018

4. Transition challenges

The auto sector is primed for electrification. Globally, electric vehicles (EVs) are already a significant player in the market of 2Ws, 3Ws, and buses. The popularity of EVs as passenger cars is also growing, with the current fleet size of electric passenger cars being about 10 million (Figure 1). In fact, other than heavy commercial vehicles (HCVs), EVs will achieve parity with conventional vehicles within two to five years in all segments. In HCVs as well, EVs are already viable in some markets for short-distance haul.[10] For a longer distance, it will take another 10 years to reach market parity.

Figure 1: Global EV sales and fleet size



Source: Electric Vehicle Outlook, 2021, Bloomberg NEF

Electrification of the automobile sector is also becoming a reality for India. While the sales of EVs is still modest (238,120 units[11] or 1.6% of all vehicles sold), this is likely to change soon. Backed by government policies such as the National Mission on Transformative Mobility and Battery Storage and Faster Adoption and Manufacturing of (Hybrid) and EV (FAME) scheme, sales of EVs are likely to witness an exponential growth in the next five to 10 years. According to IEA (2021), more than 30% of new vehicle sales in India will be electric by 2030.[12]

The above technological transition will not lead to job losses. The auto sector in India, in fact, will employ more people as the sales of vehicles are projected to increase in all segments. But some job losses can be expected in the sub-sectors of the auto component manufacturing segment.

The automobile sector, however, will see major restructuring in employment because the disruption will be in terms of change in technology. For example:

- As EVs have lesser number of components than the internal combustion (IC) engines, many auto component manufacturers involved in manufacturing of IC engines and related components will see phasing down of their operations. On the other hand, the businesses involved in electric motors will see a major increase in demand. Reskilling, therefore, is going to be very important for the auto component sector.
- The servicing sector related to the automobile industry will need huge reskilling, given the skills that will be required to service EVs. A targeted effort will be required to reskill the informal sector involved in servicing.
- The employment related to dealerships should largely remain unchanged.

Chapter 8
Fertilizer

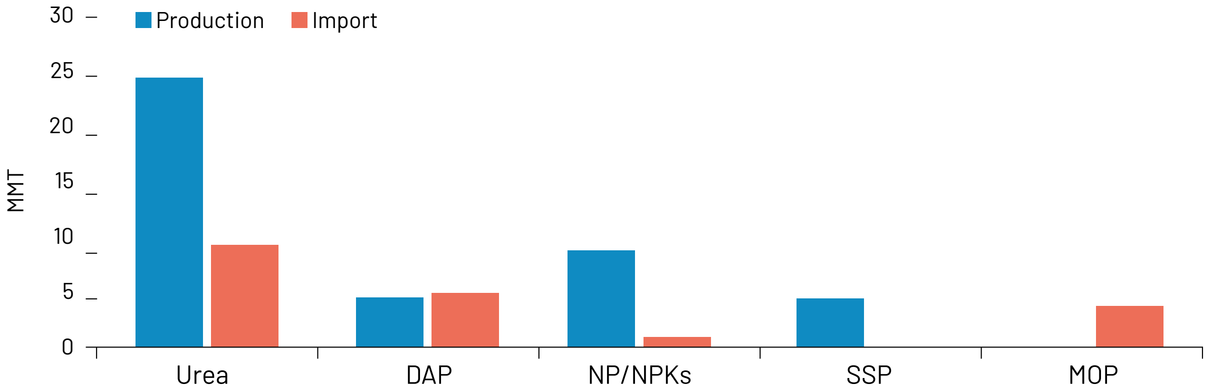
The nitrogenous fertilizers, particularly urea (which dominates India's fertilizer sector), is a significant GHG contributor. While emission from production processes constitutes only a small part of the lifecycle GHG emission, the major share of emissions for urea is related to its use in the field. The use of urea contributes to emission of CO_2 and nitrous oxide (N_2O), which is an extremely potent GHG.[1] It is estimated that application of a tonne of urea leads to 1.1 tonnes of CO_2 emission, and N_2O emission equivalent to 3.13 tonnes of CO_2. Greenhouse gas emission beyond the gate of a fertilizer plant, thus, amounts to 4.22 MT CO_2e/MT of urea consumed[2], which is 6-7 times the CO_2 emission from production plants.

Considering that India consumed 33.5 million metric tonnes (MMT) of urea in 2019–20, the total CO_2 emission from urea use would amount to 141 MT CO_2e. In the same year, the GHG emission from the urea plants was 17.5 MT CO_2e.[3] The just transition in the urea sector is, therefore, as much about changing the agricultural practices, as it is about changing the urea production technology.

1. Production, import and consumption

India's fertilizer sector accounts for the largest share of natural gas consumption. Among this, the highest consumption is for urea production. Urea is the main fertilizer produced and used in the country's agricultural sector. In 2019-20, the total production of urea, Di-ammonium Phosphate (DAP), nitrogen, phosphorus, and potassium (NP/NPKs) and single super phosphate (SSP) is estimated to be about 42 MMT.[4] Out of this, the share of urea was about 58.3% (24.5 MMT). Additionally, India also imported about 18.5 MMT of fertilizers (Figure 1), much of which was also urea.

Figure 1: Production and import of fertilizers (2019-20)



Source: Adopted from Fertiliser Association of India, 2020

The total consumption of fertilizer in India in 2019-20 was 56 MMT. Of this, the share of urea fertilizers was about 60%.[5] Over the years, the consumption of urea has dominated fertilizer use, owing to government policies and high subsidies (Table 1).

Table 1: Year-wise consumption of fertilizers in India (MMT)

Year-wise	Urea	DAP	MOP	NPKs
2015-16	30.6	9.1	2.5	8.8
2016-17	29.6	8.9	2.8	8.4
2017-18	29.9	9.3	3.1	8.6
2018-19	31.4	9.2	2.9	9.0
2019-20	33.5	10.0	2.8	9.6

Source: Department of Fertilizers, 2021 and Fertiliser Association of India, 2020; Note: MOP= Muriate of Potash

2. Urea plants – spatial distribution and employment

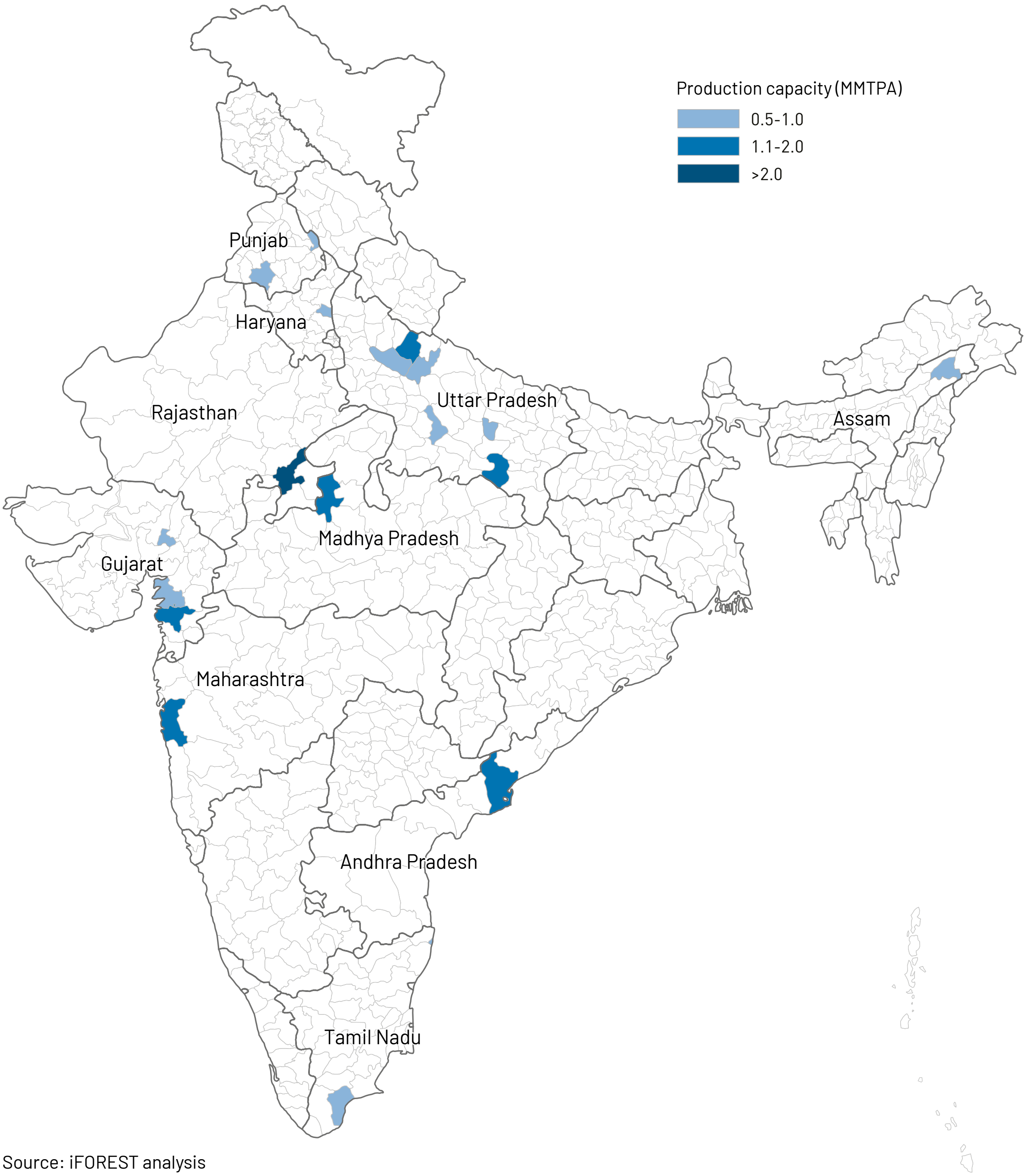
There are currently 31 operational urea plants in the country with a cumulative production capacity of nearly 24 MMT (Table 2). All of them are gas-based units expect for two, one in Mangaluru and one in Tuticorin which run on Naphtha. The private sector is the dominant player, running 13 gas-based units, followed by the public sector (10 gas-based units). Besides, six units are run by co-operatives. The urea plants are highly concentrated in Uttar Pradesh, which has eight plants with over 8 MMT capacity. Half of these plants are run by co-operatives (IIFCO) and the rest are private. Gujarat and Rajasthan are the other key states (Map 1).

Table 2: Details of urea plants (2019)

State	District	Unit name	Reassessed capacity (MMT)	Production (MMT)
Andhra Pradesh	East Godavari	Nagarjuna Fertilizers and Chemical Limited (NFCL)-Kakinada I	0.6	0.39
	East Godavari	Nagarjuna Fertilizers and Chemical Limited (NFCL)-Kakinada II	0.6	0.2
Assam	Dibrugarh	Brahmaputra Valley Fertilizer Corporation Limited (BVFCL)-Namrup III	0.32	0.23
	Dibrugarh	Brahmaputra Valley Fertilizer Corporation Limited (BVFCL)-Namrup II	0.24	0.06
Goa	South Goa	Zuari Agro-Chemicals Limited (ZACL)-Goa	0.4	0.41
Gujarat	Surat	Krishak Bharti Cooperative Limited (KRIBHCO)- Hazira	1.73	2.24
	Bharuch	Gujarat Narmada Valley Fertilizers Co. Limited (GNFC)-Bharuch	0.64	0.65
	Gandhinagar	Indian Farmer Fertiliser Corporation Limited (IFFCO)- Kalol	0.55	0.6
	Baroda	Gujarat State Fertilizers & Chemicals Limited (GSFC)-Baroda	0.37	0.37
Haryana	Panipat	National Fertilizers Limited (NFL)-Panipat	0.51	0.58
Karnataka	Dakshina Kannada	Mangalore Chemicals & Fertilisers Limited (MCF)- Mangalore	0.38	0.35
Madhya Pradesh	Guna	National Fertilizers Limited (NFL)-Vijaipur II	0.87	1.18
	Guna	National Fertilizers Limited (NFL)-Vijaipur Pur I	0.87	1.06
Maharashtra	Raigad	Rashtriya Chemicals & Fertilizers (RCF) Limited-Thal	1.71	1.98
	Mumbai Suburban	Rashtriya Chemicals & Fertilizers Limited (RCF)-Trombay-V	0.33	0.39
Punjab	Bhatinda	National Fertilizers Limited (NFL)-Bhatinda	0.51	0.6
	Rupnagar	National Fertilizers Limited (NFL)-Nangal	0.48	0.54
Rajasthan	Kota	Shriram Fertilisers and Chemicals Limited (SFC)-Kota	0.38	0.39
	Kota	Chambal Fertilisers and Chemicals Limited (CFCL) I- Gadepan	0.87	1.13
	Kota	Chambal Fertilisers and Chemicals Limited (CFCL) II- Gadepan	0.87	0.99
	Kota	Chambal Fertilisers and Chemicals Limited (CFCL) III- Gadepan	1.27	0.38
Tamil Nadu	Chennai (Madras)	Madras Fertilizers Limited (MFL)-Chennai	0.49	0.39
	Thoothukudi	Southern Petrochemical Industries Corporation Limited (SPIC)-Tuticorin	0.62	0.65
Uttar Pradesh	Budaun	Yara Fertilisers India Pvt Limited-Babrala	0.87	1.3
	Amethi	Indo Gulf Fertilisers (IGF)- Jagdishpur	0.87	1.14
	Bareilly	Indian Farmer Fertiliser Corporation Limited (IFFCO), Aonla-I	0.87	1.12
	Bareilly	Indian Farmer Fertiliser Corporation Limited (IFFCO), Aonla-II	0.87	1.12
	Shahjahanpur	KRIBHCO Fertilizers Limited (KFL)-Shahjahanpur	0.87	1.06
	Prayagraj	Indian Farmer Fertiliser Corporation Limited (IFFCO), Phulpur-II	0.87	1.05
	Prayagraj	Indian Farmer Fertiliser Corporation Limited (IFFCO), Phulpur-I	0.55	0.67
	Kanpur	Kanpur Fertilizers & Cement Limited (KFCL)	0.72	0.67
Total			**22**	**23.9**

Source: Report of the Standing Committee on Chemicals and Fertilizers, 2019-20

Map 1: Distribution of urea plants



Source: iFOREST analysis

3. Employment

The employment figures for all urea plants are not available. However, formal/direct employment with some of the major public sector companies and co-operatives is available. Based on available employment data, an employment factor approach has been followed to estimate the overall employment scenario of operational urea plants. The total formal employment can be estimated to be 0.02 million across India (Table 3).

However, the total employment in urea plants is far higher considering the engagement of informal workers in the sector. Considering the National Sample Survey (NSS) estimates on the ratio of formal and informal workers in the manufacturing sector,[6] it can be estimated that about 0.25 million people are employed informally in the urea plants. Overall, 0.27 million people are employed in manufacturing urea.

Beyond the direct employment in the urea units, the number of people employed in the transportation and distribution sector linked to urea is likely to be much higher and remains unaccounted for so far.

Table 3: District-wise formal employment in urea plants

State	District	Estimated manpower
Rajasthan	Kota	2,673
Gujarat	Surat	2,074
Uttar Pradesh	Bareilly	2,073
Madhya Pradesh	Guna	2,066
Maharashtra	Raigad	1,835
Uttar Pradesh	Prayagraj	1,590
Uttar Pradesh	Budaun	1,203
Uttar Pradesh	Amethi	1,052
Uttar Pradesh	Shahjahanpur	984
Uttar Pradesh	Kanpur	620
Tamin Nadu	Thoothukudi	603
Gujarat	Bharuch	597
Punjab	Bhatinda	558
Gujarat	Gandhinagar	557
Andhra Pradesh	East Godavari	542
Haryana	Panipat	538
Punjab	Rupnagar	501
Goa	South Goa	379
Tamil Nadu	Chennai (Madras)	364
Maharashtra	Mumbai Suburban	363
Gujarat	Baroda	343
Karnataka	Dakshina Kannada	323
Assam	Dibrugarh	266
Total		**22,105**

Source: iFOREST analysis

4. Just Transition

On the environmental front, the world has breached the planetary limit for nitrogen, with excessive use of nitrogenous fertilizer being the primary cause. Only 33% of the nitrogen that is applied through fertilizers is taken up by the plants in the form of nitrates. This is called Nitrogen Use Efficiency (NUE). The remaining 67% remains in the soil and seeps into the surrounding environment, causing surface and groundwater pollution as well as a cascade of environmental and health impacts.

It is estimated that India loses nitrogen worth US $10 billion per year as fertilizer value, while the costs of nitrogen pollution on health ecosystems and climate are calculated to be US$ 75 billion per year year (as per Society for Conservation of Nature's estimates of 2017).[7] In addition, urea production and use is a fast-growing contributor to global climate change. Hence, both the environmental and health costs of nitrogen pollution must be taken seriously and addressed quickly to ensure food security and environmental sustainability.

4.1 Technology change

A significant share of CO_2 emission from urea production is a result of the use of hydrocarbons as feedstock to produce hydrogen. In a climate-constrained world, it is imperative that less carbon-intensive methods be developed and used for hydrogen production.

Hydrogen can also be produced through electrolysis of water. Additionally, if the electricity needed for this process is produced from renewables, the entire chain could be made carbon-neutral. In fact, electrolysis was a common means of producing hydrogen in areas with cheap power before hydrocarbon-based processes took over. Fertilizer Corporation of India's Nangal plant employed electrolysis to produce hydrogen until it switched to hydrocarbons (then LSHS and fuel oil) in the 1970s due to shortage of power in the Bhakra grid.

Modern electrolytic systems for hydrogen include alkaline-based technology, proton exchange membrane (PEM) electrolysis and solid oxide electrolysis cells (SOEC). Of these, alkaline systems are the best developed, with the lowest capital costs. However, their efficiency is low, increasing their energy costs. While the current cost of hydrogen produced from electricity (particularly renewables) is high, it is expected to fall with the reducing cost of renewables.

Despite high cost, small initiatives towards electrolytic production of hydrogen are being taken up. Yara, a leading global ammonia producer, is setting up a small solar-powered electrolytic plant to produce hydrogen for ammonia production at its facility in Pilbara, Australia.[8] However, these technologies are likely to become mainstream only in the 2030s.

Another alternative is the use of biomass, including crop residues, organic municipal solid waste, animal waste, etc. for hydrogen production. Hydrogen may be produced from biomass through multiple processes, including gasification and pyrolysis, and then used in ammonia synthesis. These are not yet commercially viable for the scale required for a urea plant, but are likely to mature in the coming years.

Overall, Indian urea sector will see shift towards green hydrogen only in 2030s. As these are only technological changes, reskilling and development of new skilled manpower is the key for this sector.

4.2 Changes in agriculture practices

The largest potential to reduce the GHG and other environmental impacts is to optimise the use of urea in agriculture.

The efficiency of fertilizer use is poor in India and significant quantities of nutrients are lost without being taken up by the plants. Nitrogen use efficiency in India is 35% for lowland rice and under 50% for upland crops.[9] Efficiency may be improved through several means, including adjusting application rates based on precise estimation of crop needs (e.g., precision farming), using slow or controlled-release fertilizers (CRF) or nitrification inhibitors, which slow the microbial processes leading to N_2O formation. Applying nitrogen when it is least susceptible to loss—just prior to plant uptake (improved timing)—placing nitrogen more precisely into the soil to make it more accessible to the roots of crops, and avoiding nitrogen application in excess of immediate plant requirements are other possible ways.[10] In this regard, the government's initiative of mandating neem-coating urea is a positive step as it promotes the slower release of nitrogen, leading to enhanced efficiency of use. But the use of more effective nitrification, hydrolysis, and urease inhibitors also holds potential.

Similarly, fertigation (injection of water-soluble fertilizers into an irrigation system) allows frequent supply of nutrients and ensures application of nutrients only to the wet soil volume where roots are active, which reduces loss of nutrients by leaching. Moreover, runoff due to wind is avoided with this method. Hence, it will help reduce overall fertilizer use at the field level and promote better yields. For this, the government needs to promote drip irrigation.

Overall, for a just transition, the urea sector and the agriculture sector will have a massive requirement of training and capacity building as well as policies to promote efficient and renewable-based technologies.

Annexure 1

Assessment of GHG emission reduction potential and technology readiness

Sectors	Sub-sector	GHG emissions (% of India's total)	Main fuel/ emissions	Key technologies or best available options for emission reduction	Technology readiness for large-scale deployment	
					Years from present	Assessment
Mining, processing and storage	Coal	0.7	Fugitive CH4	Phased mine closure	0-30 years	Closure of non-profitable and UG mines over the next 10 years
	Oil and Gas	0.8	Fugitive CH4	Reduced flaring and methane capture, reduction in oil and gas extraction	1-2 years	Flaring reduction and methane capture economically viable and available
Thermal power	Coal	42	Coal/ CO_2	Renewables and storage	5 years	24x7 renewables outcompetes Coal power before 2030. Next 10 years crucial for battery storage and smart grid development. Solar and wind are already cost competitive[1]
	Gas	1.6	Natural gas/ CO_2	Renewables and storage	20 years	Scope to increase gas-based power for peaking if economically viable. Reduction can be planned after 2040
	Oil	0.3	Oil/CO_2	Renewables and storage	0	24x7 Renewables already cheaper than oil-based power
Transport	Trucks	4.4	Diesel/CO_2	Electric, biofuels and hydrogen	15 years	Biofuels already viable. Hydrogen and electric in 15 years[2]
	2-3 wheelers	2	Petrol/CO_2	Electric	0	Already viable. Massive scaling up projected in the next 10 years
	Passenger cars	2	Petrol and Diesel/ CO_2	Electric	3 years	In 2-3 years
	Other road transport	1.4	Petrol and Diesel/ CO_2	Electric	0	City buses already viable
	Civil aviation	0.6	ATF/CO_2	Electric- electrification of ground operations in aircraft (taxiing)	> 20	No clear timeframe for India
	Railways	0.3	Diesel/CO_2	Already highly electrified	0	100% electrification by 2023; Net zero carbon by 2035
	Navigation	0.1	Diesel and furnace oil/ CO_2	Electric, biofuels and hydrogen	10-15 years	Technology in process of development and demonstration

Sectors	Sub-sector	GHG emissions (% of India's total)	Main fuel/ emissions	Key technologies or best available options for emission reduction	Technology readiness for large-scale deployment	
					Years from present	Assessment
Industrial	Brick	0.4	Coal/ CO_2	Intermediate technologies like zig-zag, porous, perforated, hollow bricks/blocks, fly ash brick, AAC etc. are available and commercially viable. But clay bricks will have to be phased-out in the next two-three decades to meet climate and other ecological goals	20 years	Intermediate technologies already available, needs scaling up through market support. Clay bricks to be replaced with sustainable building materials in next 2-3 decades
	Refinery	2.8	Oil/CO_2	Improvements in efficiency and reduction in flaring	1-2 years	Cost competitive
	Iron and steel	5.4	Coal/ CO_2	Scrap-based electric arc furnaces (EAF), hydrogen-based direct reduced iron (DRI) facilities, iron ore electrolysis and ancillary equipment electrification	> 15 years	Hydrogen-based DRI & Iron ore electrolysis in 15 years
	Cement	6.3	Coal & process emissions/ CO_2	Alternative fuels and Supplementary Cementitious Materials (SCM)[3]	5 years	A 25% thermal substitution rate and 0.5 clinker: cement ratio is achievable by 2025-2030. Other technologies not in sight. CCUS consideration of long-term future
	Fertilizer	0.7	Gas/CO_2	Hydrogen to produce ammonia	15 years	Green ammonia production technology currently in process of development and demonstration[4]
	Other industries	8	Coal, oil & gas/ CO_2	Renewable based captive power plants, heat pumps, and electric, biofuels and hydrogen boilers and furnaces and high efficiency motors	5 years	In contrast to heavy industries, most of the technologies required for deep emission reductions in this sub-sector are available in the market and can be deployed in scale in the next 5 years.. This is in because more than 90% of total heat demand is low/medium temperature, which can be more readily and efficiently electrified
Residential		5	Oil, gas & biomass/ CO_2	Energy efficiency, super-efficient appliances and electric cooking	1-5 years	Technologies available at commercial scale. Can be mainstreamed in 1-5 years
Commercials/Institutional		3	Coal, Oil and gas/ CO_2	Energy efficiency, electric boilers and electrification (heat pumps)	5	Most of the technologies required for deep emission reductions in this sub-sector are available in the market and can be deployed in scale in the next 5 years
Agriculture	Agricultural soils (urea)	2.7	N_2O	Reduction of urea use through better agricultural practices is the easiest option. The use of bio-fertilizers (such as manure) is also important	Ongoing	This is available, only requires change in farming practices and policy push

Annexure 2

Potential job loss and reskilling scenarios from sectoral transitions

Sector	Activity	Production process-Labour intensity		Labour distribution	Indirect labour, Transportation	Key transition mechanism to reduce GHG emissions	Job loss vs reskilling scenario
		Mechanized	Manual				
Coal	Mining	Mechanization increasing over years in mining activities; reduction in formal and skilled labour	High dependence on manual labour in old coal regions for loading, unloading and various mining activities	Predominantly informal	Road (very significant, for major PSUs about 50% of production being transported by road) and rail	Phasing down of operations, including closures	Primarily job loss of informal workers and reskilling of skilled manpower
Crude oil	Extraction	Highly mechanized		Predominantly formal	Pipeline	No significant phase down	NA
Natural Gas	Extraction	Highly mechanized		Predominantly formal	Pipeline	No significant phase down	NA
Refining	Production of petroleum products	Highly mechanized		Predominantly formal	Road, pipeline and rail	Change in production process	Some job loss can be anticipated in refineries as refining activities reduces after 2 decades; reskilling and retraining also significant
	Marketing and distribution		Manual labour significant in retail centres and also LPG distribution	More informal		Repurposing of facilities retail facilities, phasing down of LPG distribution over time.	Primarily reskilling and retraining for marketing; for LPG distribution job loss
Coal-based thermal power	Production	Mechanized		Predominantly formal	Grid	Phasing down of operations, including closures	Job loss for unskilled and informal, reskilling of skilled
Steel	Production of iron and steel (including crude and finished)	Mechanized	Manual labour in loading, unloading, waste management etc.	Formal including contractual in main production process significant	Rail and road	Change in production process	Reskilling and retraining

Sector	Activity	Production process-Labour intensity		Labour distribution	Indirect labour, Transportation	Key transition mechanism to reduce GHG emissions	Job loss vs reskilling scenario
		Mechanized	Manual				
Cement	Production	Mechanized	Manual labour in loading, unloading, waste management etc.	Formal including contractual in main production process significant, however has implication for huge amount of employment in related manufacturing and construction sector	Rail and road	Change in production process	Reskilling and retraining
Fertilizer	Production and application on soil	Mechanized	Application in farms, labour intensive		Rail and road	Change in application and process	Reskilling and retraining

Annexure 3

Consumption of various petroleum products (2019-20) and replacement technology/ fuels

Product name	Annual con-sump-tion (MMT)	Share of total consumption in end-uses (%)											Replacement technology
		Trans-porta-tion*	Re-sellers/	Industry/ Commer-cial	Petro-chemi-cals	Domestic distribu-tion	Power genera-tion	Fertiliz-ers	Planta-tion/	Mining & Quarry-ing	Manu-factur-ing	Miscel-laneous/ Pvt. Imports	
			Retail						Agricul-ture				
HSD	82.6	7.3	85.6	1.6		0	0.3		0.7	1.9		2.6	Electric, biofuel and hydrogen
Petrol	29.98		99.6									0.4	Electric
LPG	26.3	0.7		9.9		87.6	0.004		0.1		0.6	1.1	Electric and biogas
Pet Coke	21.7			100									Pet coke used as fuel replaced by electricity and hy-drogen. Pet coke used as feed-stock; non-fossil alternatives not available
Naphtha	14.3				76.2		0.003	1.05				22.73	Naphtha used as fuel replaced by electricity and hy-drogen. Naphtha used as feedstock to remain
Aviation fuel	8												No technology in near term
LDO	0.6	0.8	6.1	54.5			24.4		1.9	2.2		10	Electric, biofuel and hydrogen
Furnace Oil	5.9	14.4	4.9	36.2			5.1		1.2	1.4		36.7	Electric, biofuel and hydrogen

Product name	Annual consumption (MMT)	Share of total consumption in end-uses (%)											Replacement technology
		Transportation*	Resellers/	Industry/ Commercial	Petrochemicals	Domestic distribution	Power generation	Fertilizers	Plantation/	Mining & Quarrying	Manufacturing	Miscellaneous/ Pvt. Imports	
SKO/ Kerosene	2.4			3.6		90.7						5.7	Electricity & biogas
Low Sulphur Heavy Stock	0.4		29	51.8			4.6		1.6			12.9	Electric, biofuel and hydrogen
Lubes and Greases	3.8												Continued use
Bitumen	6.7												Continued use
Waxes	0.3												Continued use
Others	11.1												
Total	214.1												

Source: Ministry of Petroleum and Natural Gas, 2021, * Reflects fuel transportation

References

Summary for Stakeholders

1. Labour Bureau, Ministry of Labour and Employment. (2015). Employment in Informal Sector and Conditions of Informal Employment. Volume IV, 2013-14. Government of India. https://labour.gov.in/sites/default/files/Report%20vol%20 4%20final.pdf
2. NSS data as cited in Venumuddala, V.R. (2020). Informal Labour in India. Indian Institute of Management, Bangalore. https://arxiv.org/pdf/2005.06795.pdf
3. Ibid
4. Estimated by iFOREST based on the following land-factor: Land with coal companies is about 0.22 million ha; For coal-based power, land requirement is 0.4 ha/MW, for iron and steel it is 250 ha/million MT and for cement it is 40 ha/million MT.
5. Central Coalfields Limited's mine lease area in Ramgarh is about 10% of the district's total area.
6. Parikh, V., Jijo, M. & Aritua, B. (2018). How can new infrastructure accelerate creation of more and better jobs? World Bank Blogs. https://blogs.worldbank.org/jobs/how-can-new-infrastructure-acceler¬ate-creation-more-and-better-jobs.
7. Lahiri-Dutt, K. (2014). Between Legitimacy and Illegality: Informal Coal Mining at the Limits of Justice. In Lahiri-Dutt, K. (Ed.), The Coal Nation: Histories, Ecologies and Politics of Coal in India. Page 39-62. Ashgate Publishing Limited, Surrey, England.
8. Prayas (Energy Group). 2021. Energy: Taxes and Transition in India. Working Paper.
9. Bhushan, C., Banerjee, S. and Agarwal, S. (2020). Just Transition in India: An inquiry into the challenges and opportunities for a post-coal future. International Forum for Environment, Sustainability & Technology, New Delhi, India.
10. Ibid

SECTION I: FOSSIL FUELS

Chapter 1: Coal

1. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
2. Global carbon Atlas, (2021). CO2 emissions. http://www.globalcarbonatlas.org/en/CO2-emissions
3. TERI-Shell. (2021). India: transforming to a net zero emissions energy system. Shell. https://www.shell.in/promos/energy-and-innovation/india-scenario-sketch/_jcr_content.stream/1617850096430/4dc1d51b4d29c3dfea47f0a57e9eef62000a021b/india-transforming-to-a-net-zero-emissions-energy-system-scenario-sketch-report.pdf
4. Coal India Limited. (2020). Annual Report 2019-2020. A Government of India Undertaking. https://www.coalindia.in/media/documents/Coal_India_English__final.pdf
5. Bhushan, C., Banerjee, S. and Agarwal, S. (2020). Just Transition in India: An inquiry into the challenges and opportunities for a post-coal future. International Forum for Environment, Sustainability & Technology, New Delhi, India.
6. Ibid
7. NITI Aayog. (2021). Domestic coal consumption trend. https://niti.gov.in/edm/#coalConsumption
8. Ministry of Statistic and Programme Implementation. (2021). Energy Statistics 2021. Government of India. http://www.mospi.nic.in/sites/default/files/reports_and_publication/ES/Energy%20Statistics%20India%202021.pdf
9. NITI Aayog. (2021). Domestic coal consumption trend. https://niti.gov.in/edm/#coalConsumption
10. Ministry of Statistic and Programme Implementation. (2021). Energy Statistics 2021. Government of India. http://www.mospi.nic.in/sites/default/files/reports_and_publication/ES/Energy%20Statistics%20India%202021.pdf
11. Central Institute of Mining and Fuel Research. (2014). Setting up for modalities for normative coal requirement in respect of cement and sponge iron industries. https://www.ccai.co.in/circular-policies/cil/cil-report-july-2014-regarding-normative-coal-requirement-for-cement-sponge-iron-industries.pdf
12. Department for Promotion of Industry and Internal Trade. (2020). Annual Report 2019-20. Ministry of Commerce and Industry, Government of India. https://dipp.gov.in/sites/default/files/annualReport_English2019-20.pdf
13. Calculated considering coal-based sponge iron production of 27.8 MT (2018-19, as most complete available data), and the requirement of 951 kg of coal per tonne of production.
14. NITI Aayog. (2021). Coal overview. https://niti.gov.in/edm/#coal
15. Pai, S; Zerriffi, H. and Kaluarachchi, S. (2021). Indian coal mine location and production - December 2020. Harvard Dataverse, V1. https://doi.org/10.7910/DVN/TDEK8O
16. Ibid
17. World Bank. (2020). Coal rents (% of GDP)-India. https://data.worldbank.org/indicator/NY.GDP.COAL.RT.ZS?end=2019&locations=IN&start=2015

18. Prayas (Energy Group). 2021. Energy Taxes and Transition in India. Working Paper. https://www.prayaspune.org/peg/publications/item/485-energy-taxes-and-transition-in-india.html
19. Ibid
20. Ministry of Coal. Press Information Bureau. (2020). States to garner ₹ 6,656 Crores of annual revenue from the historic success of nation's first commercial coal mining auction: Shri Pralhad Joshi. https://pib.gov.in/Pressreleaseshare.aspx?PRID=1671487
21. State revenue calculations based on- Reserve Bank of India. 2021. State Finances: A Study of Budgets; State revenue from coal PSUs based on company annual reports and accounts
22. The Goods and Services Tax (Compensation to States) Act. (2017). Government of India. https://legislative.gov.in/sites/default/files/A2017-15_2.pdf
23. Ministry of Mines. (2021). DMF/PMKKKY dashboard
24. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
25. Indian Railways. (2021). Annual reports and accounts 2019-20. Government of India. https://indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/Annual-Reports-2019-2020/Indian-Railways-Annual%20-Report-Accounts%20-2019-20-English.pdf
26. These include workers working in the mines and washeries, executives working in coal company offices and support staff.
27. Pai, S. and Zerriffi, H. (2021). A novel dataset for analysing sub-national socioeconomic developments in the Indian coal industry. IOP Sci Notes. https://iopscience.iop.org/article/10.1088/2633-1357/abdbbb/pdf
28. Pai, S., Zerriffi, H., Kaluarachchi, S. (2021). Indian coal mine location and production - December 2020. Harvard Dataverse, V1. https://doi.org/10.7910/DVN/TDEK8O,
29. NSS data as cited in Venumuddala, V.R. (2020). Informal Labour in India. Indian Institute of Management, Bangalore. https://arxiv.org/pdf/2005.06795.pdf
30. Lahiri-Dutt, K. (2014). Between Legitimacy and Illegality: Informal Coal Mining at the Limits of Justice. In Lahiri-Dutt, K. (Ed.), The Coal Nation: Histories, Ecologies and Politics of Coal in India. Page 39-62. Ashgate Publishing Limited, Surrey, England.
31. Central Electricity Authority. (2020). Draft report on optimal generation capacity mix for 2029-30. Ministry of Power, Government of India
32. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
33. Ibid
34. Bose, P.R. (2017, June 01). CIL plans to shut down 65 loss-making mines. The Hindu Business Line. https://www.thehindubusinessline.com/companies/cil-plans-to-shut-down-65-lossmaking-mines/article9717877.ece
35. Coal India Limited. (2020). Annual Report 2019-2020. https://www.coalindia.in/media/documents/Coal_India_English__final.pdf
36. Coal India Limited. (2020). Annual Report 2019-2020. Page 189. https://www.coalindia.in/media/documents/Coal_India_English__final.pdf
37. Arora, S., Malakar, B. (2020, December 26). Coal India set to diversify into non-coal mining areas in 2021. Mint. https://www.livemint.com/companies/news/coal-india-set-to-diversify-into-non-coal-mining-areas-in-2021-11608968548890.html
38. Press Trust of India. (2018, April 01). Coal India sets 20 GW solar power generation target in next 10 yrs. ET Energy World. https://energy.economictimes.indiatimes.com/news/renewable/coal-india-sets-20-gw-solar-power-generation-target-in-next-10-yrs/63566675
39. Mercom India. (2021, April 22). Coal India Forms Subsidiaries for Solar Manufacturing and Renewable Energy Projects. https://mercomindia.com/coal-india-subsidiaries-solar-manufacturing-renewable/
40. Labour Bureau, Ministry of Labour and Employment. (2015). Employment in Informal Sector and Conditions of Informal Employment. Volume IV, 2013-14. Government of India. https://labour.gov.in/sites/default/files/Report%20vol%204%20final.pdf
41. Bhushan, C., Banerjee, S. and Agarwal, S. (2020). Just Transition in India: An inquiry into the challenges and opportunities for a post-coal future. International Forum for Environment, Sustainability & Technology, New Delhi, India.
42. Lahiri-Dutt, K. (2014). Between Legitimacy and Illegality: Informal Coal Mining at the Limits of Justice. In Lahiri-Dutt, K. (Ed.), The Coal Nation: Histories, Ecologies and Politics of Coal in India. Page 39-62. Ashgate Publishing Limited, Surrey, England.
43. Bhushan, C., Banerjee, S. and Agarwal, S. (2020). Just Transition in India: An inquiry into the challenges and opportunities for a post-coal future. International Forum for Environment, Sustainability & Technology, New Delhi, India.
44. ibid
45. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021

Chapter 2: Oil

1. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris. https://www.iea.org/reports/india-energy-outlook-2021
2. Kah, M. (2018). Electric vehicles and their impact on oil demand: Why forecasts differ. Centre on Global Energy Policy. Columbia University. USA. https://energypolicy.columbia.edu/sites/default/files/pictures/CGEP_Electric%20Vehicles%20and%20Their%20Impact%20on%20Oil%20Demand-Why%20Forecasts%20Differ.pdf
3. Ministry of Petroleum and Natural Gas. (2021). Indian Petroleum and Natural Gas Statistics 2019-20. Government of India
4. Ministry of Statistics and Programme Implementation. (2021). Energy Statistics 2021. Government of India. http://mospi.nic.in/sites/default/files/reports_and_publication/ES/Energy%20Statistics%20India%202021.pdf
5. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris. https://www.iea.org/reports/india-energy-outlook-2021
6. Ministry of Petroleum and Natural Gas. (2021). Indian Petroleum and Natural Gas Statistics 2019-20. Government of India
7. Ibid
8. International Energy Agency. (2020). India 2020: Energy Policy Review. IEA, Paris. https://niti.gov.in/sites/default/files/2020-01/IEA-India-In-depth-review2020.pdf
9. Ministry of Petroleum and Natural Gas. (2016). Indian Petroleum and Natural Gas Statistics 2015-16. Government of India http://petroleum.nic.in/sites/default/files/pngstat_1.pdf
10. International Energy Agency. (2020). India 2020: Energy Policy Review. IEA, Paris. https://niti.gov.in/sites/default/files/2020-01/IEA-India-In-depth-review2020.pdf
11. NITI Aayog. (2021). Energy Dashboard-Oil consumption. http://www.niti.gov.in/edm/#oilConsumption
12. U.S Energy Information Administration. (2020). Country Analysis Executive Summary: India. https://www.eia.gov/international/content/analysis/countries_long/India/india.pdf
13. Petroleum Planning & Analysis Cell. Ministry of Petroleum and Natural Gas. (2021). State-wise retail outlets data. Government of India.
14. Ministry of Petroleum and Natural Gas. (2021, March 17). RAJYA SABHA UNSTARRED QUESTION NO.2535. Government of India. https://pqars.nic.in/annex/253/Au2535.pdf
15. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris. https://www.iea.org/reports/india-energy-outlook-2021
16. Petroleum Planning & Analysis Cell. Ministry of Petroleum and Natural Gas. (2021). State-wise retail outlets data. Government of India.
17. Ibid
18. Ministry of Petroleum and Natural Gas. (2021). Indian Petroleum and Natural Gas Statistics 2019-20. Government of India
19. Nayara Energy. (2021). Retail footprint. https://www.nayaraenergy.com/retail-footprint
20. Jacob, S. (2019, August 7). Reliance, BP announce JV to set up 5,500 petrol pumps; RIL to hold 51%. Business Standard. https://www.business-standard.com/article/companies/reliance-bp-announce-jv-to-set-up-5-500-petrol-pumps-ril-to-hold-51-119080601048_1.html
21. Labour Bureau. Ministry of Labour and Employment. (2011). Working conditions of the contract workers in Petroleum Refineries and Oil fields 2009-11. Government Of India. http://labourbureau.gov.in/CL_WC_Pet_Ref.pdf?pr_id=7Lfk2NwJIyc%3D
22. Ibid, page 21
23. Ministry of Petroleum and Natural Gas. (2015). Indian Petroleum and Natural Gas Statistics 2014-15. Government of India. https://mopng.gov.in/files/TableManagements/pngstat_2.pdf
24. The retail employment has been calculated using the thumb-rule of minimum 16 employee per outlet with monthly sales of 170 kilolitres. This thumb-rule is used by OMCs for calculating commissions of the outlets.
25. Jacob, S. (2017, December 23). Minimum wages for petrol pump employees stayed oil firms suffer setback. Business Standard. https://www.business-standard.com/article/economy-policy/minimum-wages-for-petrol-pump-employees-stayed-oil-firms-suffer-setback-117122200834_1.html
26. Workers estimated considering 2 office staff and 2 loaders/unloaders (who also do delivery) as per letter of intents of OMCs
27. World Bank. (2020). Oil rents (% of GDP)-India. https://data.worldbank.org/indicator/NY.GDP.PETR.RT.ZS?locations=IN
28. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
29. Ibid
30. Ibid
31. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021

32. Shell-The Energy and Resources Institute. (2021). India: Transforming to a net-zero emissions energy system. https://www.shell.in/energy-and-innovation/new-sketch-india-transforming-to-a-net-zero-emissions-energy-system.html
33. Pradhan Mantri Ujjwala Yojana. Government of India. (2021). https://www.india.gov.in/spotlight/pradhan-mantri-ujjwala-yojana#tab=tab-4
34. Patnaik, S., Tripathi, S. and Jain, A. (2019). Roadmap for Access to Clean Cooking Energy in India. Council on Energy, Environment and Water. New Delhi, India. Report.pdfhttps://niti.gov.in/sites/default/files/2019-11/CEEW-Roadmap_for_Access_to_Clean_Cooking_Energy_in_India-Report.pdf
35. Ministry of Petroleum and Natural Gas. https://mopng.gov.in/en/pdc/investible-projects/oil-amp-gas-infrastructure/city-gas-distribution
36. Electric cooking starts to simmer in rural India (2019, November 5). https://energy.economictimes.indiatimes.com/news/oil-and-gas/electric-cooking-starts-to-simmer-in-rural-india/71825232
37. Gudde, N. J. (2018). Adaptation of oil refineries to make modern fuels. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 232(1), 5–21
38. Govt to set up EV charging kiosks at 69,000 petrol pumps across India. (2020, November 24). https://www.financialexpress.com/auto/electric-vehicles/govt-to-set-up-ev-charging-kiosks-at-69000-petrol-pumps-across-india/2135090/
39. International Energy Agency. (2020). Global EV Outlook 2020. IEA, Paris. https://iea.blob.core.windows.net/assets/af46e012-18c2-44d6-becd-bad21fa844fd/Global_EV_Outlook_2020.pdf

Chapter 3: Natural Gas

1. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
2. TERI-Shell. (2021). India: transforming to a net zero emissions energy system. Shell. https://www.shell.in/promos/energy-and-innovation/india-scenario-sketch/_jcr_content.stream/1617850096430/4dc1d51b4d29c3dfea47f0a57e9eef62000a021b/india-transforming-to-a-net-zero-emissions-energy-system-scenario-sketch-report.pdf
3. Staff reporter (Anon). Business Today. India's oil and gas sector to see 300 billion investments by 2030. (2020, October 26). https://www.businesstoday.in/sectors/energy/india-oil-gas-sector-to-see-300-billion-investment-by-2030/story/419921.html
4. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
5. Nisbet, E.G. et. al. (2019). Very strong atmospheric Methane growth in the 4 years 2014-2017: Implication for the Paris Agreement. Global Biogeochemical Cycles, Vol 33 (3), page: 318-342. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GB006009
6. Shindell, D. et al. (2009). Improved Attribution of Climate Forcing to Emissions. Science, Vol. 326, No. 5953, page: 716-718. https://science.sciencemag.org/content/326/5953/716
7. International Energy Agency. (2012). Golden rules for a golden age of gas: World Energy Outlook special report on unconventional gas. IEA, Paris, France. https://iea.blob.core.windows.net/assets/8422ef9a-9ae8-4637-ab1c-ddb160ab7c59/WEO_2012_Special_Report_Golden_Rules_for_a_Golden_Age_of_Gas.pdf
8. Ministry of Petroleum and Natural Gas. (2021). Indian Petroleum and Natural Gas Statistics 2019-20. Government of India. https://mopng.gov.in/files/TableManagements/IPNG-2019-20.pdf
9. Ministry of Petroleum and Natural Gas. (2021). Indian Petroleum and Natural Gas Statistics 2019-20. Government of India. https://mopng.gov.in/files/TableManagements/IPNG-2019-20.pdf

SECTION II: INDUSTRIES

Chapter 4: Coal-based Thermal Power

1. Central Electricity Authority. (2020). Growth of Electricity Sector in India 1947-2020. Ministry of Power, Government of India. https://cea.nic.in/wp-content/uploads/pdm/2020/12/growth_2020.pdf
2. Bhushan, C., Banerjee, S. and Agarwal, S. (2020). Just Transition in India: An inquiry into the challenges and opportunities for a post-coal future. International Forum for Environment, Sustainability & Technology, New Delhi, India.
3. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
4. Bhushan, C., Banerjee, S. and Agarwal, S. (2020). Just Transition in India: An inquiry into the challenges and opportunities for a post-coal future. International Forum for Environment, Sustainability & Technology, New Delhi, India.
5. Central Electricity Authority. (2020). Growth of Electricity Sector in India 1947-2020. Ministry of Power, Government of India. https://cea.nic.in/wp-content/uploads/pdm/2020/12/growth_2020.pdf

6. Ibid
7. Timperley, J. (2019, March 14). The Carbon Brief Profile: India. Carbon Brief. https://www.carbonbrief.org/the-carbon-brief-profile-india
8. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris. https://www.iea.org/reports/india-energy-outlook-2021
9. Central Electricity Authority. (2018). Carbon Emissions from Power Sector. Government of India. http://erpc.gov.in/wp-content/uploads/2018/06/carbon-emissions-from-power-sector-7062018.pdf
10. Central Electricity Authority. (2018). Carbon Emissions from Power Sector. Government of India. http://erpc.gov.in/wp-content/uploads/2018/06/carbon-emissions-from-power-sector-7062018.pdf
11. Ministry of Power, Government of India. (2021). Power Sector at a Glance, All India. https://powermin.gov.in/en/content/power-sector-glance-all-india
12. Central Electricity Authority. (2018). National Electricity Plan. Ministry of Power, Government of India. https://cea.nic.in/wp-content/uploads/2020/04/nep_jan_2018.pdf
13. As per interaction with labour unions and industry workers in the districts of Chhattisgarh.
14. Ministry of Power. (2020, November 28). "Increasing storage and democratising RE deployment will be next frontier for the Government of India" Power Minister Shri R K Singh at valedictory session of 3rd Global Re-Invest. Government of India. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1676863
15. National Thermal Power Corporation. (2021). Renewable Energy. https://www.ntpc.co.in/en/power-generation/renewable-energy
16. National Thermal Power Corporation. (2021). New and Renewable Energy. https://www.ntpc.co.in/en/services-and-initiatives/netra/key-issues-and-mandates/new-renewable-energy
17. International Energy Agency. (2021). India Energy Outlook 2021. Paris. France. https://www.iea.org/reports/india-energy-outlook-2021

Chapter 5: Iron and Steel

1. Ministry of Steel. National Steel Policy. (2017). National Steel Policy 2017. Government of India. https://steel.gov.in/sites/default/files/draft-national-steel-policy-2017.pdf
2. International Energy Agency. (2020). Iron and Steel Technology Roadmap: Towards more sustainable steelmaking. Paris, France. https://www.iea.org/reports/iron-and-steel-technology-roadmap
3. Ibid
4. Joint Plant Committee, Ministry of Steel. (2020). The Indian Iron and Steel Database, 2019-20. Government of India
5. Ibid
6. Ministry of Steel. (2021). Annual Report, 2020-21. Government of India. https://steel.gov.in/sites/default/files/Annual%20Report-Ministry%20of%20Steel%202020-21.pdf
7. As per National Steel Policy 2017, Govt estimates were about 2.5 lakhs. But crude steel production has also increased 5 MT between 2016 to 2019.
8. NSS data as cited in Venumuddala, V.R. (2020). Informal Labour in India. Indian Institute of Management, Bangalore. https://arxiv.org/pdf/2005.06795.pdf
9. Jain A. (2019, May 24). India's Road Towards Being an Economic Powerhouse Is Paved On Steel. Invest India. International Investment Promotion and Facilitation Agency https://www.investindia.gov.in/team-india-blogs/indias-road-towards-being-economic-powerhouse-paved-steel
10. International Energy Agency. (2020). Iron and Steel Technology Roadmap: Towards more sustainable steelmaking. Paris, France. https://www.iea.org/reports/iron-and-steel-technology-roadmap
11. Ibid
12. A scale used to assess where a technology is on its journey from initial idea to maturity; the IEA uses a scale with 11 increments which are grouped into six categories: Concept (TRL 1-3), Small prototype (TRL 4), Large prototype (TRL 5-6), Demonstration (TRL 7-8), Early adoption (TRL 9-10) and Mature (TRL 11)
13. Hall, W., Spencer, T. and Kumar, S. (2020). Towards a low-carbon steel sector. The Energy and Resources Institute (TERI). New Delhi, India. https://www.teriin.org/sites/default/files/2020-01/towards-low-carbon-sector.pdf
14. International Energy Agency. (2020). Iron and Steel Technology Roadmap: Towards more sustainable steelmaking. Paris, France. https://www.iea.org/reports/iron-and-steel-technology-roadmap

Chapter 6: Cement

1. International Energy Agency. (2020), Cement, IEA, Paris. https://www.iea.org/reports/cement

2. The Government of India has been laying a massive emphasis on infrastructure development, with 100 smart cities, modernisation of 500 cities, affordable housing for all by 2022, cement concreting of national highways, provision of sanitation facilities, etc.
3. Department for Promotion of Industry and Internal Trade. (2021). Annual Report 2020-21. Government of India. https://dipp.gov.in/sites/default/files/annualReport-English2020-21.pdf
4. World Business Council for Sustainable Development. (2019). Indian Cement Sector SDG Roadmap. https://www.wbcsd.org/contentwbc/download/7018/116131/1
5. International Energy Agency. (2018). Cement technology roadmap plots path to cutting CO2 emissions 24% by 2050. Paris, France. https://www.iea.org/news/cement-technology-roadmap-plots-path-to-cutting-co2-emissions-24-by-2050
6. Bureau of Energy Efficiency. (2018). Improving Energy Efficiency in Cement Sector: Achievement and way forward. BEE-GIZ. https://www.keralaenergy.gov.in/files/Resources/Cement_Sector_Report_2018.pdf
7. Friedlingstein et al. (2020). Global Carbon Project (Global Carbon Atlas). http://www.globalcarbonatlas.org/en/CO2-emissions
8. United Nations. (2015). Paris Agreement, [Preamble, para 10] https://unfccc.int/files/essential_background/convention/application/pdf/english_par¬is_agreement.pdf
9. Indian Bureau of Mines. (2020). Indian Minerals Yearbook, Cement. Government of India. https://ibm.gov.in/writereaddata/files/07072020143800Cement_2019.pdf
10. Ibid
11. Department for Promotion of Industry and Internal Trade. (2021). Annual Report 2020-21. Government of India. https://dipp.gov.in/sites/default/files/annualReport-English2020-21.pdf
12. World Business Council for Sustainable Development. (2019). Indian Cement Sector SDG Roadmap. https://www.wbcsd.org/contentwbc/download/7018/116131/1
13. Indian Bureau of Mines. (2020). Indian Minerals Yearbook, Cement. Government of India. https://ibm.gov.in/writereaddata/files/07072020143800Cement_2019.pdf
14. Statista Research Department. (2021). Consumption volume of cement in India from financial year 2009 to 2018 with an estimate for financial year 2019. https://www.statista.com/statistics/269322/cement-consumption-in-india-since-2004/
15. World Business Council for Sustainable Development. (2019). Indian Cement Sector SDG Roadmap. WBCSD. https://www.wbcsd.org/contentwbc/download/7018/116131/1
16. Rajya Sabha Secretariat. (2011, February). 95th report on Performance of Cement Industry. Rajya Sabha, Parliament of India. https://dipp.gov.in/sites/default/files/Performance_Cement_Industry.pdf
17. NSS data as cited in Venumuddala, V.R. (2020). Informal Labour in India. Indian Institute of Management, Bangalore. https://arxiv.org/pdf/2005.06795.pdf
18. Cement Manufacturers Association. (2021). Indian Cement Industry- Contribution to domestic economy. https://www.cmaindia.org/indian-cement-industry-contribution-to-domestic-economy/
19. Planning Commission of India. Working Group Eleven. Government of India. https://niti.gov.in/planningcommission.gov.in/docs/aboutus/committee/wrkgrp11/wg11_cement.pdf
20. Verma, Y.K., Mazumdar, B. and Ghosh, P. (2021). Thermal energy consumption and its conservation for a cement production unit. Environmental Engineering Research. 26(3). https://www.eeer.org/journal/view.php?number=1175#:~:text=Around%2070%E2%80%9380%25%20of%20the,only%20for%205%E2%80%9310%25.
21. Confederation of Indian Industry. (2016). Promoting alternate fuel and raw material usage in Indian cement industry: Approach paper for achieving 25% Thermal Substitution Rate in Indian cement industry by 2025. Hyderabad, India. https://www.mycii.in/KmResourceApplication/50819.25TSRby2025.pdf
22. Wojtacha-Rychter, K., Kucharski, P. and Smolinski, A. (2021). Conventional and Alternative Sources of Thermal Energy in the Production of Cement—An Impact on CO2 Emission. Energies. 14 (1539). https://doi.org/10.3390/en14061539
23. Bureau of Energy Efficiency. (2018). Improving Energy Efficiency in Cement Sector: Achievement and way forward. BEE-GIZ. https://www.keralaenergy.gov.in/files/Resources/Cement_Sector_Report_2018.pdf

Chapter 7: Road Transport

1. Ministry of Environment, Forest and Climate Change. (2021). India: Third Biennial Update Report to the United Nations Framework Convention on Climate Change. Government of India. https://unfccc.int/sites/default/files/resource/INDIA_%20BUR-3_20.02.2021_High.pdf
2. Ibid
3. International Energy Agency. (2021). India Energy Outlook. , Paris, France. https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf

4. Society of Indian Automobile Manufacturers. (2020). Annual Report 2019-2020. https://www.siam.in/uploads/ar/22-22ndAnnual%20Report%202019-20.pdf
5. Ibid
6. International Energy Agency. (2021). India Energy Outlook. Paris, France. https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf
7. Shah, A. (2021, May 10). Indian auto dealers predict slow sales recovery virus spreads rural areas. Reuters. https://www.reuters.com/world/india/indian-auto-dealers-predict-slow-sales-recovery-virus-spreads-rural-areas-2021-05-10/
8. International Energy Agency. (2021). India Energy Outlook. Paris, France. https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf
9. Dhawan, R., Gupta, S.& et. al (2018). The auto component Industry in India: Preparing for the future. Mckinsey & Company. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/asia%20pacific/the%20auto%20component%20industry%20in%20india%20preparing%20for%20the%20future/acma%20vertical_onscreen_final.ashx
10. Bloomberg NEF. (2021). Electric Vehicle Outlook 2021. https://about.bnef.com/electric-vehicle-outlook/#:~:text=The%20Electric%20Vehicle%20Outlook%20is,two%2Fthree%2Dwheeled%20vehicles
11. Society of Manufacturers of Electric Vehicle. (2021). EV Sales. https://www.smev.in/ev-sales
12. International Energy Agency. (2020). Global EV Outlook 2020. Paris, France. https://www.iea.org/reports/global-ev-outlook-2020

Chapter 8: Fertilizer

1. Bhushan, C. et.al. (2019). Grain by Grain: Green rating of the fertilizer sector. Centre for Science and Environment, New Delhi, India
2. Anon 2011. Carbon Footprint Reference Values, Fertilizers Europe, Brussels
3. Calculation based on Bhushan, C. et.al. (2019). Grain by Grain: Green rating of the fertilizer sector.Centre for Science and Environment, New Delhi, India
4. Fertilizer Association of India. (2020). 65th Annual Report, 2019-20. https://www.faidelhi.org/general/FAI-AR-19-20.pdf
5. Ibid
6. NSS data as cited in Venumuddala, V.R. (2020). Informal Labour in India. Indian Institute of Management, Bangalore. https://arxiv.org/pdf/2005.06795.pdf
7. Sangomla A. (2017, December 15). We have breached the planetary limit for nitrogen. Down To Earth. https:// www.downtoearth.org.in/news/agriculture/when-n-means-noxious-59279
8. Anon. (2018, June 6). Key to a sustainable future: Thyssenkrupp launches advanced water electrolysis. https://www.thyssenkrupp-industrial-solutions.com/en/media/press-releases/key-to-a-sustainable-future—thyssenkrupp-launches-advanced-water-electrolysis-1536.html
9. Chander S. (2016). Nitrogen in Indian Agriculture, Indian Journal of Fertilizers, Fertiliser Association of India, New Delhi. https://www.faidelhi.org/Frank%20 notes/IJF-April-16.pdf
10. Bellarby, J., Foereid, B., Hastings, A. and Smith, P. (2008). Cool Farming: Climate impacts of agriculture and mitigation potential, Greenpeace International, Amsterdam. http://eprints.lancs.ac.uk/68831/1/1111.pdf

Annexure 1

1. NITI Aayog. (2019). Energy Storage System, Roadmap for India: 2019-2032. Government of India
2. International Energy Agency. (2021). India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021
3. SCMs include, Geopolymer/Alkali activated cement, Calcium Sulfoaluminate (CSA) Cement, Magnesia binder, Celitement, Carbonatable Calcium Silicate cement.
4. Brown, T. (2019). Renewable hydrogen sustainable ammonia production. https://www.aiche.org/resources/publications/cep/2019/august/renewable-hydrogen-sustainable-ammonia-production

iFOREST | INTERNATIONAL FORUM FOR ENVIRONMENT, SUSTAINABILITY & TECHNOLOGY

https://iforest.global/

International Forum for Environment, Sustainability & Technology (iFOREST) is an independent non-profit environmental research and innovation organisation. It seeks to find, promote and scale up solutions for some of the most pressing environment-development challenges. It also endeavours to make environmental protection a peoples' movement by informing and engaging the citizenry on important issues and programs.