



Australian Government  
Department of Industry and Science

Office of the  
Chief Economist



# Coal in India

2015

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An aerial photograph of a densely packed, hilly town, likely in India, with many small, light-colored buildings. The town is built on a hillside, and the buildings are closely packed together. The image is overlaid with a dark blue gradient.

# Coal in India 2015

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JUNE 2015





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# Foreword

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World energy consumption is likely to be one of the defining issues of the 21st century, particularly the way in which the world simultaneously addresses climate change and access to energy. Energy markets are evolving with government policies and technological advancements supporting rapid growth in renewable energy capacity. What is often overlooked is that even in recent years the use of fossil fuels has grown by even more in aggregate terms than renewables. Many OECD countries have already delivered on commitments to reduce their use of coal and oil, but this has been more than offset by higher consumption in highly populated emerging economies such as China, India and South-East Asia.

Many emerging economies are still investing in coal-fired electricity generation to ensure reliable, low-cost electricity access to support their industrial expansion and growing populations. While the focus of energy and coal market analysis in the past decade has been on China, India is now emerging as a key consumer. India's thermal coal imports have increased from almost zero in the 1990s to having it overtake Japan as the world's second largest importer in 2013.

The *Coal in India* report is intended to contribute to the debate by examining the energy policies and regulatory settings that will influence the outlook for India's coal industry, highlight the role of coal in improving energy access, and discuss how technical advances can reduce growth in India's carbon intensity. In doing so, it identifies opportunities for Australian producers and mining equipment and technology services companies in meeting India's growing demand.

I highly recommend *Coal in India* to anyone seeking to develop a greater understanding of the factors shaping the growth in India's coal use over the longer term.



Mark Cully  
Chief Economist  
Department of Industry and Science

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# Abbreviations and acronyms

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AUSC	advanced ultra-supercritical (coal plant)
CCS	carbon capture and storage
CIL	Coal India Limited
COP	conference of parties
CPS	current policies scenario
CSP	concentrated solar power
DWT	deadweight tonnes
FDI	foreign direct investment
FYP	five-year plan
Gcal	gigacalorie
GDP	gross domestic product
GW	gigawatt
GWh	gigawatt hour
HELE	high efficiency, low emissions
HHV	higher heating value
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
INDC	intended nationally determined contribution
kcal	kilocalorie
kWh	kilowatt hour
MBtu	million British thermal units
METS	mining equipment, technology and services
MNRE	Ministry of New and Renewable Energy
MOC	Ministry of Coal
MOP	Ministry of Power
MOPNG	Ministry of Petroleum and Natural Gas
Mtce	million tonnes of coal equivalent
Mtoe	million tonnes of oil equivalent

MW	megawatt
NEEPCO	North Eastern Electric Power Corporation
NHPC	National Hydroelectric Power Corporation
NITI	National Institution for Transforming India
NPS	new policies scenario
NTPC	National Thermal Power Corporation
OECD	Organisation for Economic Co-operation and Development
PCC	pulverised coal combustion
PSU	public sector undertaking
PV	photovoltaic
ROM	run of mine
SCCL	Singareni Collieries Company Limited
TJ	terajoule
TWh	terawatt hour
UHV	useful heating value
UMPP	ultra mega power plant
UNFCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical
WEO	world energy outlook



# Executive Summary

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India is the world's third largest energy consumer, and its energy use is projected to grow at a rapid pace supported by economic development, urbanisation, improved electricity access and an expanding manufacturing base. By 2040, the International Energy Agency projects that India's energy consumption will be more than OECD Europe combined, and approaching that of the United States.

India's energy sector is governed by a complex institutional structure that requires heavy interaction across Ministries and jurisdictions. Accordingly, policy development or the introduction of reforms to the sector can be difficult, which has contributed to ongoing weakness in energy policy and provision, including inadequate energy delivery infrastructure and control and co-ordination issues.

To meet its growing energy requirements, India is developing all available technology options. The Government has set ambitious targets to increase the installed capacity of renewable technologies to 175 gigawatts in 2022 (from around 65 gigawatts in early 2015). India is also rapidly expanding its coal-fired electricity generation capacity, with around 113 gigawatts of new capacity already under construction or approved in addition to the 205 gigawatts of existing capacity. In 2012, coal-fired electricity accounted for 60 per cent of India's installed capacity and 71 per cent of its electricity generation. Given the investment underway in the sector, coal will remain a key input into India's electricity generation.

India's coal-fired electricity generation capacity is largely based on subcritical technology and is designed to use domestically-sourced coal. Although subcritical technology is relatively low cost compared with other available technologies, it uses more coal and generates more CO<sub>2</sub> emissions. From 2017, all new coal-fired projects developed in India are required to use supercritical technology or better. These technologies operate at a higher efficiency than subcritical plants and as such use less coal and generate fewer emissions. Plants using these technologies run more optimally using high-energy, low ash coal. India's coal resources are typically low-energy and high ash.

India is the world's third largest producer of thermal coal. While production has increased over the past few decades, the pace of growth has been insufficient to meet demand. Consequently, India has become more reliant on imported coal (thermal coal imports increased from 10 million tonnes in 2000 to 142 million tonnes in 2013). Most of India's thermal coal imports have been sourced from Indonesia because of its relatively low-cost compared with other internationally traded coal; its specifications more closely match India's domestic coal; and several Indian companies own Indonesian mines.

India's investment in new coal-fired generation capacity will support an increase in coal use. India has plans to almost double its production to one billion tonnes by 2020 to meet its growing requirements. However, growth in production is likely to be constrained by difficulties in accessing land, lengthy approval processes, inadequate transportation systems, and poor productivity largely stemming from the use of outdated production techniques. Further, the increased use of advanced coal-fired generation technologies will require high quality coal that is not available in large quantities in India. As a result, India is likely to continue to rely on imports.

The expansion in India's coal use presents some opportunities for the Australian industry, which is not currently a large supplier of thermal coal to India. Australia has large deposits of high-energy, low ash coal that is suitable for use in advanced coal-generation technologies. The roll out of advanced coal generation technologies in India presents a significant long term opportunity for coal producers. In addition, India's desire to improve the productivity and safety of domestic coal mines through advanced technology may present an opportunity for Australia's mining equipment, technology and services sector.



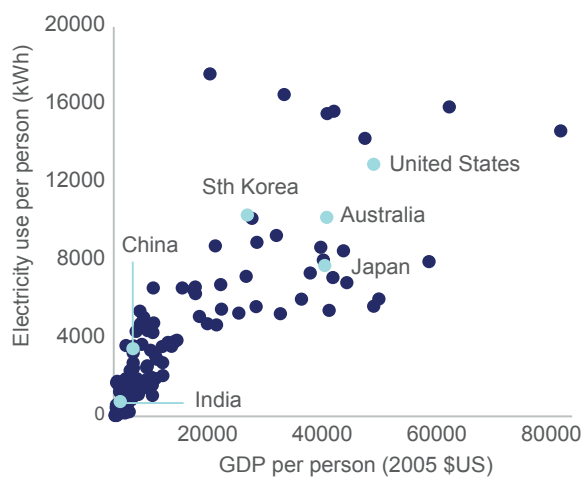
Coal is an important part of India's energy mix

India is becoming more reliant on imports.

Investment still focused on subcritical coal technologies but moving to advanced technologies.

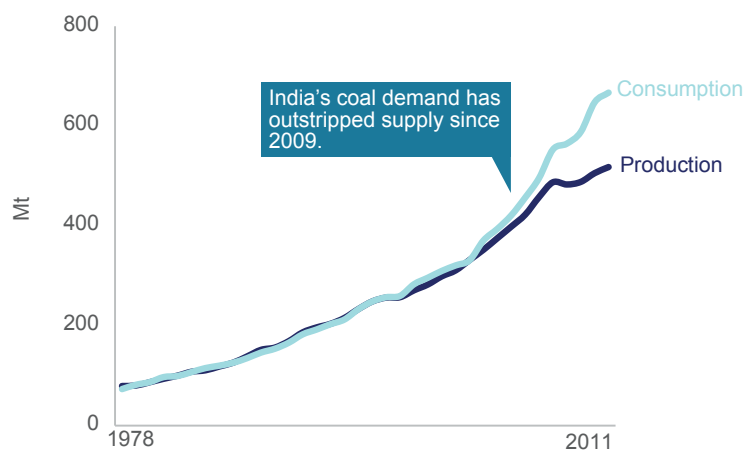
#### Opportunities for Australia

To supply high quality coal for advanced generation technologies and mining services.



India's per person electricity consumption is lower than advanced economies and many emerging economies.

Source: IEA 2014d, World Bank 2015



Despite large reserves, production growth has been well below growth in consumption over the past decade.

Source: IEA 2014f

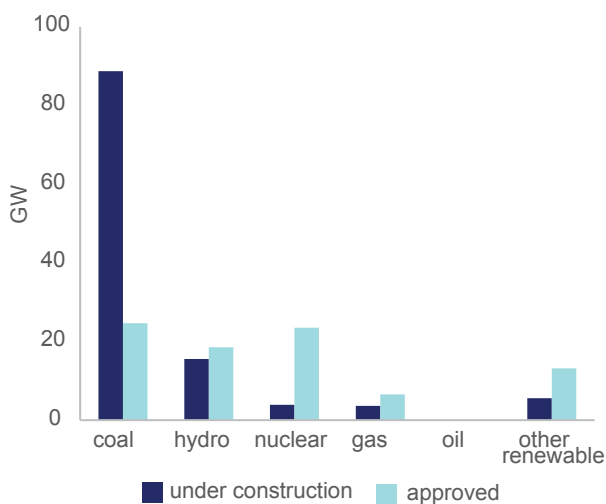
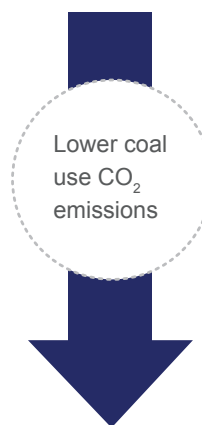
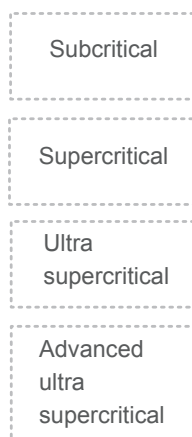




**90%** of India's coal-fired fleet uses subcritical technology.

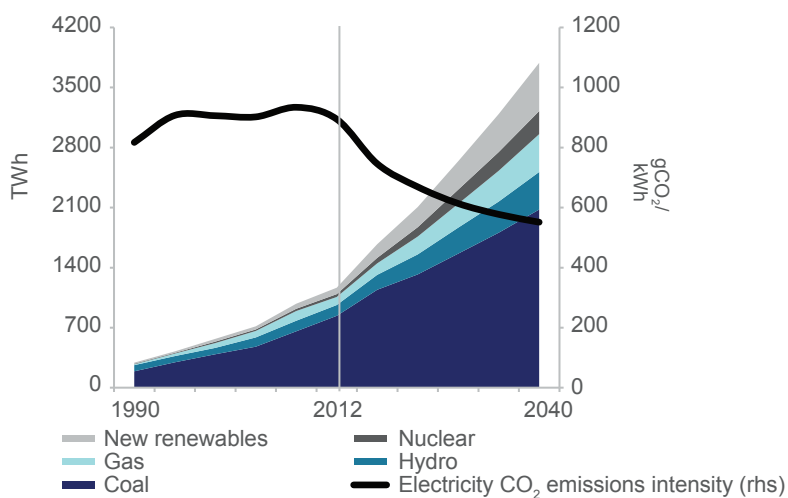


**60%** India's share of new subcritical plants being developed worldwide.



Despite impressive renewable targets, most new capacity under development is coal-based.

Source: Enerdata 2015, [www.enerdata.net](http://www.enerdata.net)



Despite increased growth in other sources, coal will remain a major source of electricity generation. Increased use of renewables, nuclear and advanced coal technology will reduce carbon intensity.

Source: IEA 2014d, IEA 2014g, IEA 2014a



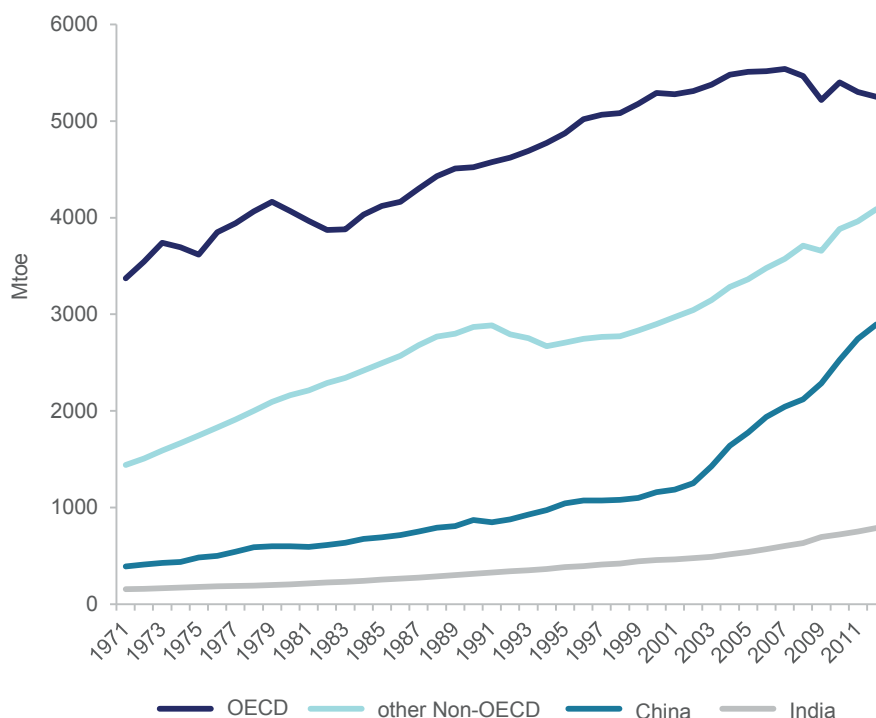
# Introduction

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It has been clear for some time that world energy consumption growth has been driven by non-OECD countries, particularly in Asia (figure 1). Much attention has understandably been focused on China given the size of its recent economic expansion and associated increase in energy requirements. However, as China's economic growth slows, and with it growth in energy and coal use, the focus is now rebalancing towards other emerging energy markets that are highly populated and positioned for a period of economic growth. India is a likely candidate to be the next main driver of world energy consumption as it meets both of these criteria. It has a population of around 1.3 billion people, many of whom still do not have access to electricity, and is already investing heavily to address the issues in its electricity markets. Furthermore, its economy is starting to exhibit robust growth rates with the recently elected Modi government providing a substantial lift in business sentiment.



Figure 1. World energy consumption



Source: IEA 2014d.

*India's energy consumption has grown substantially over the past forty years.*

India's energy consumption has grown substantially over the past forty years, with the average growth rate increasing in the new millennium. Robust economic growth, an expanding middle class and growing population have underpinned this growth, all of which are trends that are unlikely to change in the near term. Nevertheless, the challenges facing India's energy sector are immense. Despite the extended period of high growth in energy consumption, energy poverty remains a significant issue in India. The International Energy Agency (IEA) estimates that 304 million people (around 13 times Australia's total population) are unable to access any electricity and many of those that have access experience regular supply disruptions that necessitate expensive diesel back-up generators (IEA 2014c). To date, plans to develop new electricity generation capacity have fallen short of the government's ambitions and targets. Despite these shortfalls, there has still been substantial growth in India's electricity consumption and this has primarily been met through increased use of coal. Even though it has substantial coal resources, India's coal mining sector has been challenged by the growth in demand and the domestic supply response has not kept up.

India's electricity markets and the coal mining industry in India are heavily regulated and mostly managed by public institutions and both experience systemic supply disruptions. The large scale blackouts in northern and eastern India in July 2012, when up to 600 million people lost electricity access, epitomised the ongoing weaknesses in energy policy and delivery, including lack of generation and transmission capacity, control and co-ordination issues, and inadequate energy supply.

Coal is expected to play a major role in addressing some of India's energy challenges. Reflecting its large domestic reserves, coal is already a major component of India's energy supply, accounting for 45 per cent of its total energy mix, 60 per cent of installed electricity capacity and 71 per cent of electricity generation in 2012. Given the plans for investment in new coal-fired capacity, coal will continue to be a major component of India's energy mix over the longer term.

One of the key challenges facing India is balancing the energy needs of its population and growing economy with the global move to reduce carbon emissions. While investment in renewable energy sources is undoubtedly on the rise in India, there is even greater investment already underway into coal-fired electricity generation which indicates that India's coal consumption is likely to rise for some time. What remains to be seen is the role High Energy, Low Emissions technologies (HELE), such as ultra-supercritical generators, and carbon capture and storage will play in India's energy markets. Both have the potential to provide significant reductions in carbon emissions, but come with higher capital costs.

This report focuses on the trends, policies and market structures that are shaping India's electricity and coal mining industries both in the short and long term. It discusses the long term outlook for India's coal consumption, production and trade by analysing the market structures, regulatory environment, electricity consumption trends and investment that underpin them. The first chapter provides an overview of India's electricity and coal industries including the role of government, market structures and regional consumption patterns. The second chapter discusses current policies and reforms that are underway with an assessment of the effects that these may have on India's coal consumption and production.

Chapter three reviews the IEA outlook for India's coal demand and supply in the 2014 edition of the World Energy Outlook including some of the challenges to meeting planned targets. The report concludes with a discussion on the implications for Australia as a major coal exporter and potential investment destination. This report also includes a series of appendix that provide some background information on coal as a commodity, its use in electricity generation, HELE technologies, mining methods used to extract coal and trends in world coal use at the end of the report.





**DANGER**

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# India's electricity and coal markets

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India is a large energy consumer and producer, with a diverse consumer base. While its energy use has increased rapidly over the past few decades, per capita energy use in India remains well below OECD countries and many other emerging economies. Coal has played a vital role in meeting India's growing energy needs over the past few decades. Even though India is a major coal producer its output has not kept pace with demand and they have become increasingly reliant on world markets to satisfy their requirements.

There is a high level of government participation in the energy market, including the development of policies, research and development, regulation and provision of energy through Public Sector Undertakings. Although market-based mechanisms are slowly being introduced and there is increasing private sector involvement, the government remains a key player in the provision of energy.

The structure of India's energy sector is complex, relying on a high level of co-ordination and co-operation between five major Ministries. This is further complicated through the extensive interaction between central and state-based government agencies. As a result of this complexity, market operation and reforms can be difficult.

## Structure of the Indian energy sector

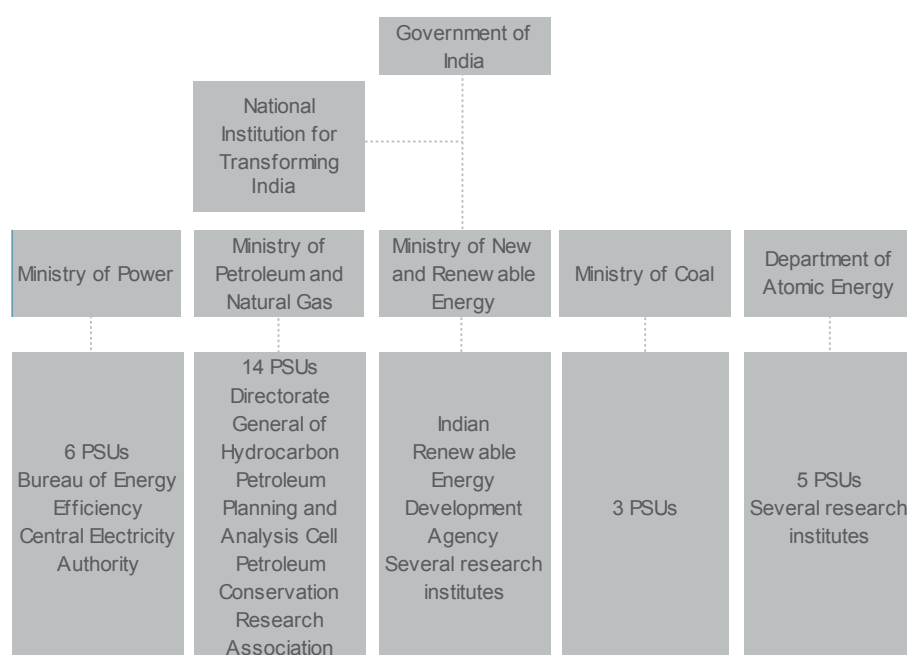
The Indian government is the principal agent in its energy market with responsibility for both setting energy policies and administering the public companies that produce energy. The institutional set-up for India's energy sector is a complex structure of five major Ministries that are directly involved in policy making,

and have responsibility for energy provision (figure 2). Overseeing these Ministries is the National Institution for Transforming India (NITI), which replaced the Planning Commission in early 2015. The NITI is designed to become a source of relevant strategic and technical advice to the central and state governments with responsibilities across the spectrum of key policy elements. The former top down model of the Planning Commission is intended to be replaced with a more consultative, co-ordinating role, especially where issues cross central-state boundaries.

Three major Ministries; Coal, Power and New and Renewable Energy, were created from a single Energy Ministry more than 20 years ago. To improve co-ordination and deliver better outcomes, the three Ministries now report to a single Minister, Piyush Goyal, following the change in government in 2014. The Ministry of Coal (MOC) has primary carriage over policies and strategies for coal production and development. The MOC has an interest in three Public Sector Undertakings (PSUs) involved in coal production. The Ministry of Power (MOP) is responsible for planning, implementing and monitoring policy in the power sector. The MOP oversees six PSUs and two statutory authorities. The Ministry of New and Renewable Energy (MNRE) takes the lead on policy development and promotion of new and renewable energy. The MNRE has several research and development institutes that are involved in testing and demonstrating various renewable technologies; and the identification of potential sites for development (IEA 2012).

The Ministry of Petroleum and Natural Gas (MOPNG) oversees India's oil and gas sectors including exploration and production, refining, distribution, marketing, pricing, and trade. The MOPNG has fourteen PSUs that produce oil and gas, and eight statutory bodies. The government has sole responsibility for nuclear power under the Indian Constitution. The Department of Atomic Energy has five PSUs, dedicated to nuclear energy production and research (IEA 2012).

**Figure 2. Institutional structure of energy administration in India**



Source: based on IEA 2012, p. 18.

## Electricity sector structure

Under the Indian Constitution, power is a shared responsibility between central and state governments (figure 3). The central government has a key role in electricity planning, and the formulation, implementation and monitoring of policy in the sector through the MOP. It also provides an oversight and coordination role for two statutory bodies (Central Electricity Authority and Bureau of Energy Efficiency) and six state-owned utilities. These agencies cover thermal and hydropower generation, transmission, distribution and financing. The state governments are also important to the Indian electricity sector as state-owned utilities control a large share of the transmission and distribution network (IEA 2012). In practice, most of the work in the electricity sector is undertaken by the states, with some engagement and support from the central government (IEA 2014b).

Government-owned utilities have a key role in supplying electricity in India, accounting for around 70 per cent of India's total electricity generation. Private utilities account for the remaining 30 per cent of electricity generation and are slowly playing a larger role in electricity provision.

## Key government power companies

The National Thermal Power Corporation (NTPC) is the largest power company in India. It has diversified from its traditional base of thermal assets to include hydropower, nuclear and renewable facilities. It operates 33 power plants, with a combined capacity of 38 gigawatts. Almost 90 per cent of its installed capacity is coal-fired. While NTPC is government-owned

it has Maharatna status, which gives it greater autonomy from the central government in decision making (NTPC 2015). Companies with Maharatna status can incur capital expenditure without any value ceiling; enter into joint-ventures or strategic alliances; restructure the organisation including opening offices abroad; and raise debt from capital markets.

The North Eastern Electric Power Corporation (NEEPCO) was established to develop electricity capacity in the north east of India. NEEPCO has 1130 megawatts of installed capacity and accounts for almost half of the installed capacity in the region (NEEPCO 2015).

The National Hydroelectric Power Corporation (NHPC) is responsible for developing hydropower, tidal, geothermal and wind-based electricity capacity. It currently has 20 plants with a combined capacity of 6500 megawatts (NHPC 2015).

### Key private power companies

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*The private sector plays a small role in the generation, transmission and distribution of electricity.*

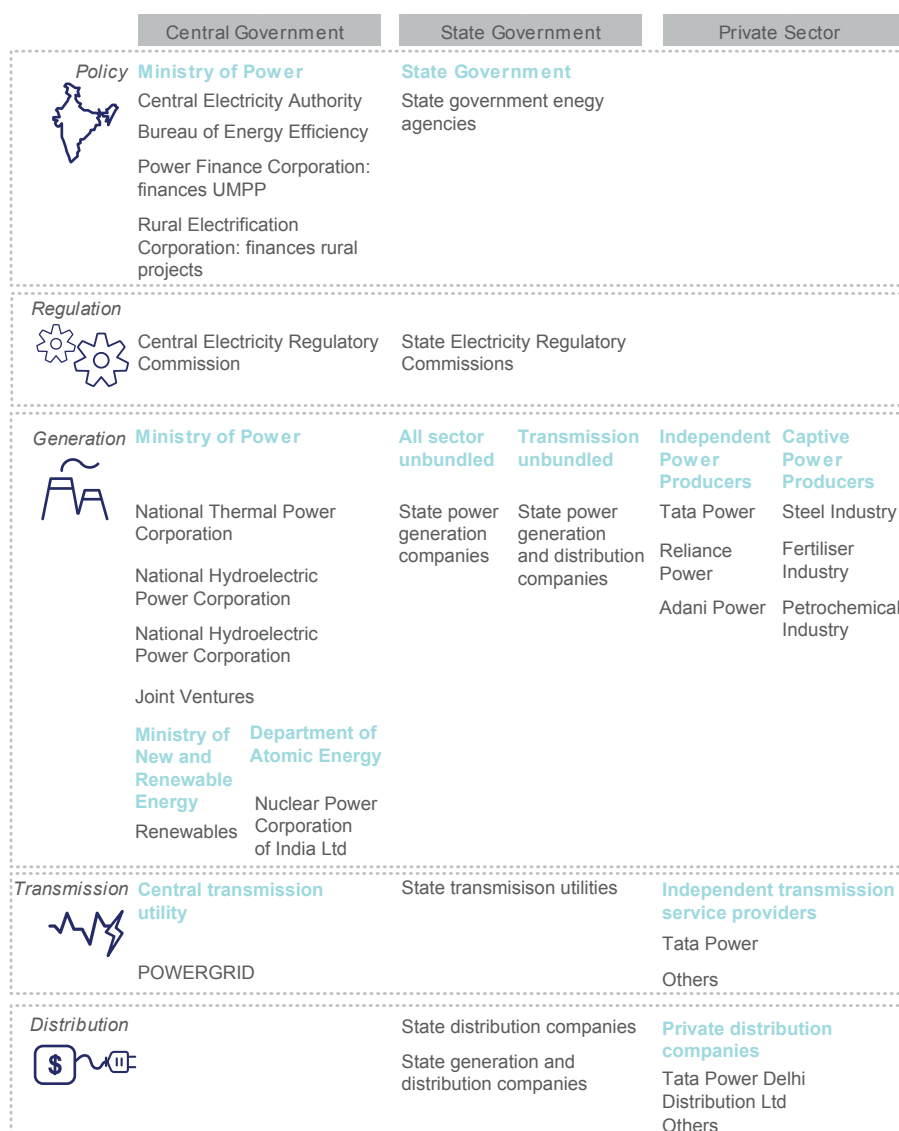
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The private sector is involved in the generation, transmission and distribution of electricity. However, they account for a relatively small share of the overall market. Adani Power is the largest private thermal power producer in India. It has an installed capacity of around 10 440 megawatts and owns India's largest power plant, Mundra, in Gujarat. The plant has nine generator units with a combined capacity of around 4620 megawatts (Adani Power 2015).

Tata Power is India's largest integrated power company. It was responsible for developing India's first 4000 megawatt Ultra Mega Power Project using supercritical technology in Gujarat. Tata Power has a total installed capacity of around 8750 megawatts based on thermal, hydro, solar and wind technologies (Tata Power 2015).

Electricity tariffs charged by central government controlled utilities and independent power producers that deliver power to more than one state are regulated by the Central Electricity Regulatory Commission (CERC). CERC also issues licences for companies transmitting electricity across states and acts as an arbitrator in disputes between companies. State Electricity Regulatory Commissions are responsible for setting tariffs for state-owned utilities (IEA 2012).

**Figure 3. Structure of India's electricity sector**



Source: IEA 2012, p. 33.

Note: UMPP is an ultra-mega power project. They are large projects using supercritical technology, with a capacity of around 4000 megawatts each.

## Coal market structure

India's domestic coal industry is primarily government owned and co-ordinated. The central government plays a key role in India's coal policy development and also owns the public companies that account for most of India's coal production (figure 4). The MOC is responsible for the formulation of policies and strategies for coal exploration, project approvals and other issues relating to the production, supply, distribution and pricing of coal in India (MOC 2014a). The Coal Controller is a subordinate office of the MOC which sets standards and procedures for assessing coal quality, inspects coal quality, performs an arbitrator role in the event of quality disputes, issues project approvals, collects excise duties and manages coal-related statistics (Coal Controller 2015).



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*Coal production in India has been controlled by the central government following the nationalisation of India's coal mines in the early 1970s.*

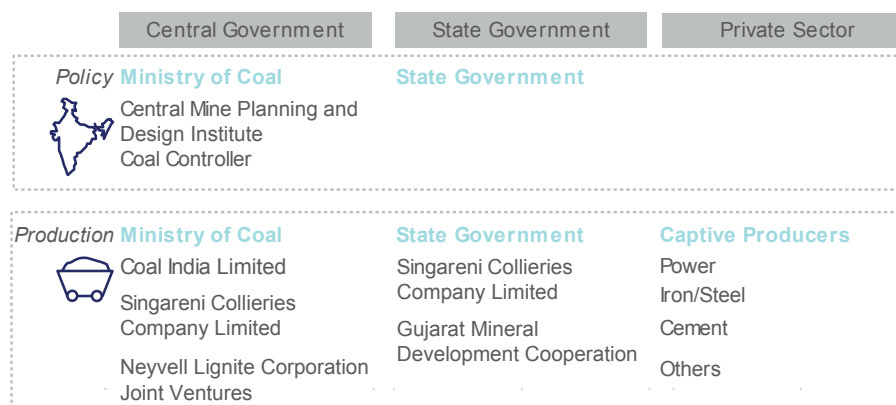
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Coal production in India has been controlled by the central government following the nationalisation of India's coal mines in the early 1970s. All metallurgical coal mines were nationalised in 1971–72 and thermal coal mines in 1973. Coal India Limited (CIL) was formed as a holding company in 1975, incorporating the state-owned companies that were created following the nationalisation of India's coal assets. Since its inception, three new state-owned subsidiaries were developed to reduce the administrative burden of companies spanning a large geographic area. CIL now has eight subsidiaries—Bharat Coking Coal Limited, Central Coalfields Limited, Eastern Coalfields Limited, Western Coalfields Limited, South Eastern Coalfields Limited, Northern Coalfields Limited, Mahanadi Coalfields Limited and the Central Mine Planning and Design Institute (MOC 2014b). The Indian Government divested a 10 per cent share in CIL in 2010 and intends to sell a further 10 per cent share during 2015 (MOC 2014c; IEA 2012; Kazmin 2015).

CIL accounts for around 80 per cent of India's total coal production. The MOC is responsible for setting production targets and other performance indicators for CIL through a dedicated Memorandum of Understanding. CIL's production target for the 2015–16 financial year (April 2015 to March 2016) has been set at 550 million tonnes, up 8.5 per cent from the previous year's target. In the previous fiscal year CIL produced 494 million tonnes, 3 per cent below its target of 507 million tonnes (Bahuguna 2015). To achieve the new target, CIL will need to produce an extra 56 million tonnes during the 2015–16 financial year.

Although the central government has primary carriage over India's coal sector, state governments retain some influence over developments through approval of mining licences and leases, which are required before the MOC grants final project approval, and royalty rates (IEA 2012).

**Figure 4. Structure of India's coal sector**



Sources: IEA 2012, p. 48; MOC 2014a.

## Energy and electricity use

India is the world's third largest energy user. In 2012, India's total primary energy demand was 788 million tonnes of oil equivalent (Mtoe), which was greater than Russia, well in excess of any IEA member except the United States, and around six times that of Australia (figure 5). India's primary energy demand in 2012 was roughly equal to China's energy consumption in 1990.

*India is the world's third largest energy user.*

### Box 1. Energy measurement

There are a few basic concepts that are used extensively in discussions about energy and will assist in understanding developments in world energy markets. **Energy** can be loosely defined to include heat, power and fuels, such as oil, gas and coal. In the context of this report, energy use refers to the direct use of crude energy that hasn't been transformed into another energy source such as electricity or refined petroleum. **Electricity** can be produced using natural energy sources such as hydro, solar and wind, through the heat of nuclear fission, geothermal or solar thermal, and the burning of combustible fuels such as coal, oil and gas.

Fuels, such as coal, oil and gas, are measured for trading and monitoring processes that produce or use them. These can be either physical units for solid fuels (tonnes or kilograms) or volume units for liquids (cubic metres or litres). These units can be converted into energy units to facilitate the aggregation of different fuels in different physical states. The most commonly used energy units are million tonnes of oil equivalent (Mtoe), joules, calories, British thermal units (Btu) and million tonnes of coal equivalent (Mtce). The conversion equivalents are expressed in table 1.

**Table 1. Conversion equivalents between units of energy**

To:	TJ	Gcal	Mtoe	MBtu	GWh
From	multiply by:				
Terajoule (TJ)	1	238.8	$2.388 \times 10^{-5}$	947.8	0.2778
Gigacalorie	$4.1868 \times 10^{-3}$	1	$10^{-7}$	3.968	$1.163 \times 10^{-3}$
Mtoe	$4.1868 \times 10^{-4}$	$10^{-7}$	1	$3.968 \times 10^7$	11630
Million Btu	$1.0551 \times 10^{-3}$	0.252	0.252	1	$2.931 \times 10^{-4}$
Gigawatt hour	3.6	860	860	3212	1

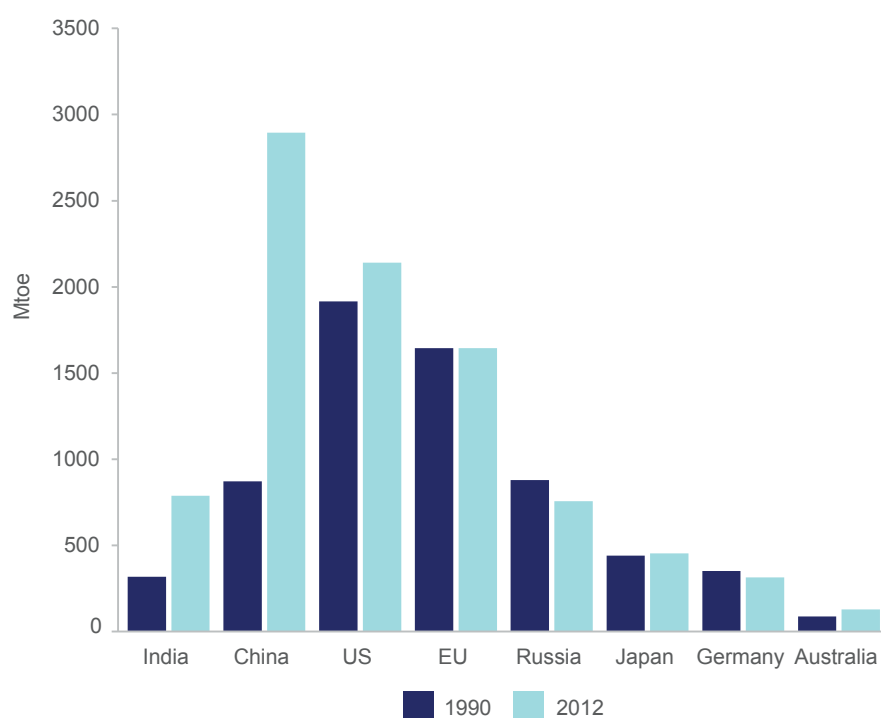
Source: IEA 2005.

The conversion of a fuel from a physical or volume unit to an energy unit requires a conversion factor that expresses the heat obtained from one unit of the fuel. This conversion factor is referred to as its **calorific value**. The quality of fuels and hence their calorific values varies across deposits and countries.

**Electrical capacity** is the maximum electricity output that can be generated at a plant under certain conditions. Capacity is typically measured in multiples of Watts. The choice of multiple (kilo, mega, giga, tera) depends on the size of the plant.

**Electricity generation** and use is the amount of electricity produced or consumed over a certain period of time. Generation and consumption are measured as a multiple of watt hours. Many electricity plants do not operate at full capacity all the time, output is varied based on operating conditions, input costs and requirements (IEA 2005).

**Figure 5. Primary energy demand**

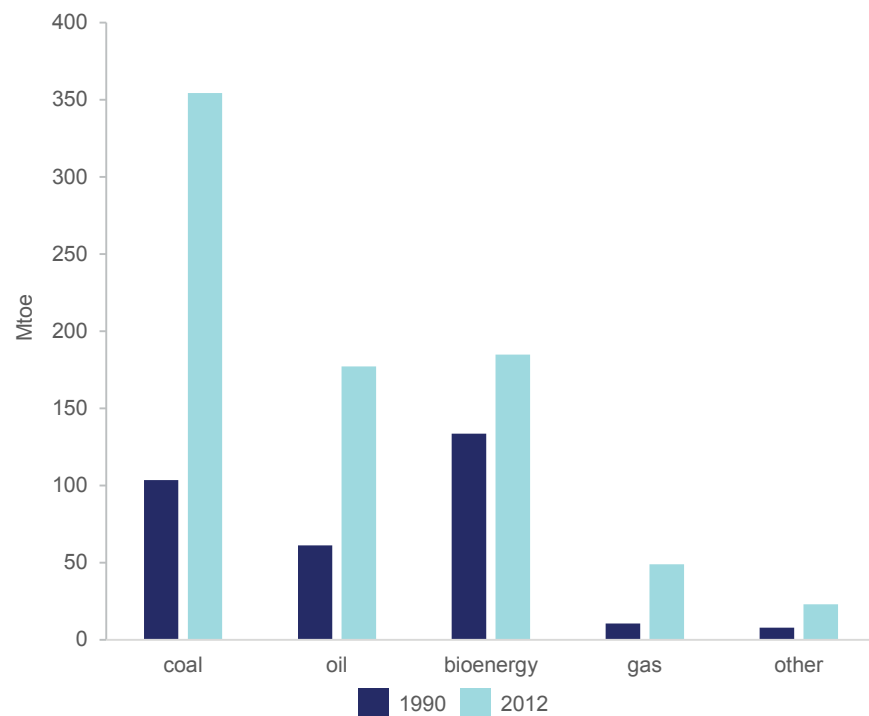


Source: IEA 2014d.

India's energy demand has roughly quadrupled since 1980, and increased two and a half times since 1990, driven by both economic and population growth. The power sector has been the main contributor to the expansion in energy use, increasing its share of total primary energy demand from 23 per cent in 1990 to 39 per cent in 2012. The building (27 per cent) and industry (22 per cent) sectors are the other major energy consuming activities in India (IEA 2014a).

Between 1990 and 2012 the composition of India's energy mix has changed sharply, with traditional biomass (such as wood used in heating and cooking) in particular losing share (figure 6). The share of coal increased to almost 45 per cent in 2012, up from 33 per cent in 1990. The low cost and reliability of coal, as well as its relative abundance in India, made it a preferred energy source in India.

**Figure 6. India's energy mix**



Source: IEA 2014d.

Energy security in India has been interpreted as a drive towards maximum levels of self-sufficiency, using domestic energy resources of hydrocarbons, bioenergy, other renewables, and even thorium (for use in nuclear power generation). This has led to an over-reliance on government-owned monopolies, and introspective policy making. Moreover, the related challenge of rapidly growing imports of fossil fuels is becoming more prominent. India imports large volumes of oil (India has limited reserves), which until recently has been putting considerable pressure on its current account deficit. Of greater concern to India is the rapid growth in gas and coal imports, because they have large reserves, where the combination of local production and transport issues have prevented output from growing at the same rate as demand. The power sector lacks the diversification of sources that most energy importers consider essential for energy security. This is reflected in the lack of diversification in energy supply sources. Around 83 per cent of India's thermal coal imports are sourced from Indonesia and 86 per cent of its gas imports are sourced from Qatar.

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*India's electricity generation quadrupled between 1990 and 2012, to 1130 terawatt hours (TWh).*

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India's electricity generation quadrupled between 1990 and 2012, to 1130 terawatt hours (TWh). In 2012 India was the world's third largest electricity producer behind China and the United States, and almost equal to Germany and France combined. However, Indian electricity generators have very high own-use requirements (electricity used at the generation plant), large transmission losses (the electricity lost during transport) in excess of 20 per



cent, and high commercial losses (from power theft). As a result, India's electricity consumption was 870 TWh, only four times higher than Australia. Given the large difference in the populations of India and Australia, this highlights the disparity in per person electricity use.

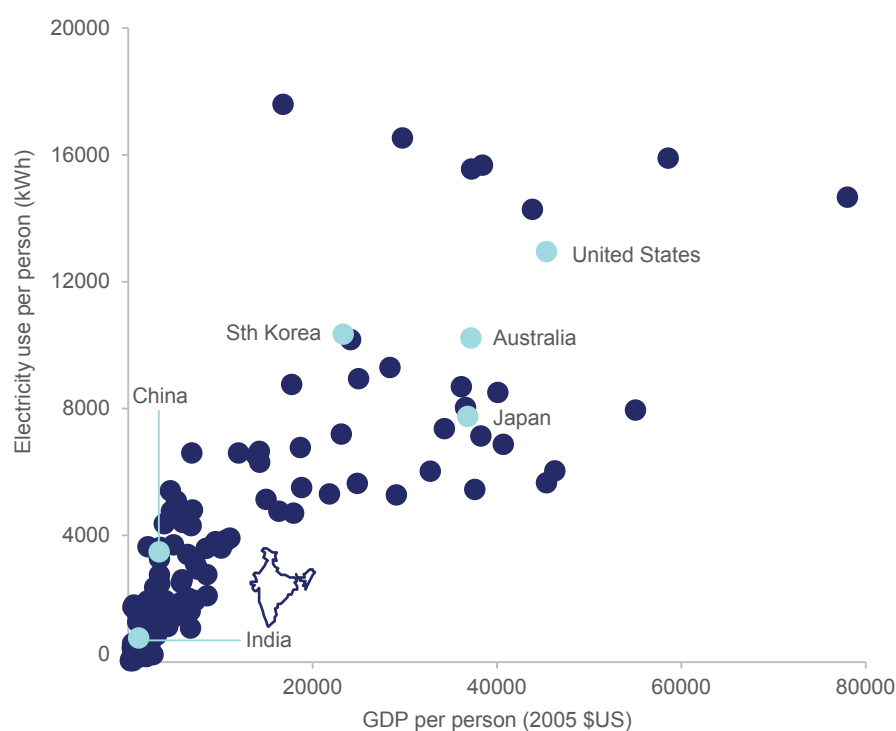
Electricity is essential to economic and human development. It supports industrialisation, improved access to clean water, sanitation and basic health as well as better education services. India's per person electricity use is very low compared with advanced economies and still low relative to other emerging economies (figure 7). India's low energy consumption per person can be attributed to a shortfall in electricity infrastructure, such as grid networks, as well as sufficient and reliable generating capacity. The IEA estimates that around 300 million people in India have inadequate access to electricity in India. This represents around a quarter of the population, with nearly 93 per cent of these 300 million people located in rural areas (IEA 2014b).

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*Electricity is essential to economic and human development.*

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**Figure 7. Electricity use and economic development, 2012**

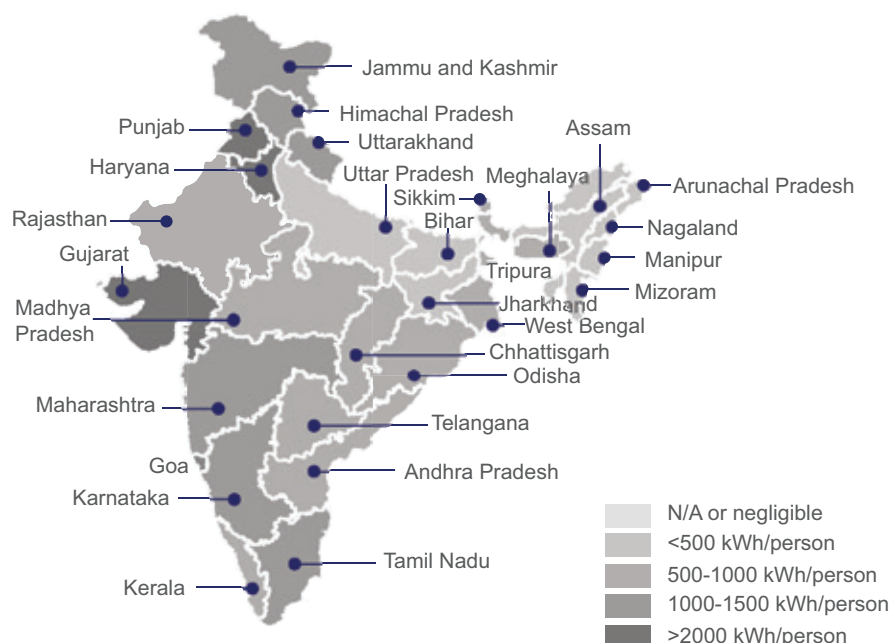


Sources: IEA 2014d, World Bank 2015.

Electricity consumption per person is not uniform in India and varies between regions (figure 8). The lowest electricity consumption per person is in the east and north-east regions, which have populations of around 271 million and 44 million people, respectively. On average, residents in Bihar consumed just 179 kilowatt hours (kWh) each during 2014. By contrast, west coast regions consumed much more electricity. In 2014, residents in

Goa consumed around 2300 kWh per person, almost 13 times the electricity consumed per person in Bihar. As a comparison, the average Australian consumes around 10 200 kWh per person which is about 4.5 times as much as a person in Goa and 57 times as much as a person in Bihar.

**Figure 8. India's electricity use per person, 2014**



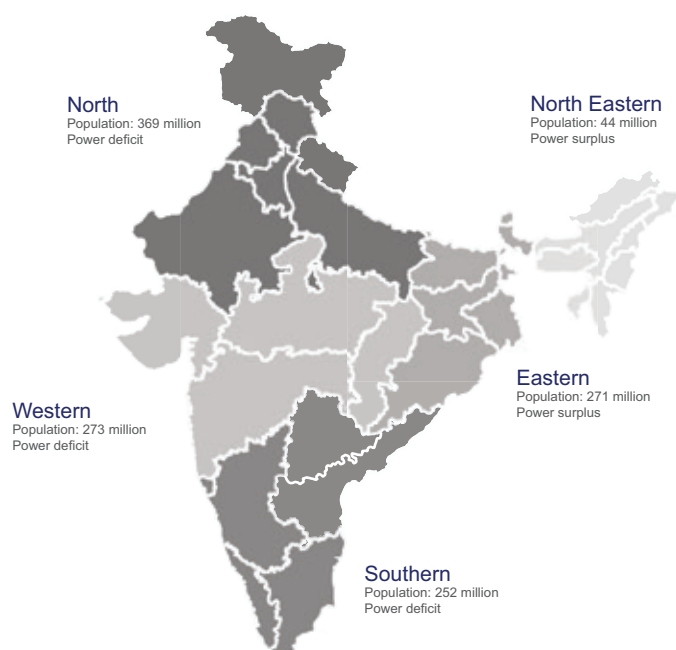
*Note:* Map shows India's territorial claims

*Source:* CEIC 2015.

The Indian electricity network comprises five regional grids—Northern, Western, Southern, Eastern and North Eastern (figure 9). These grids have been interconnected since the end of 2013, but transmission and distribution infrastructure remain underdeveloped. There is considerable diversity in the resources available for power generation between the regional grids. The best solar resources are in the West (Gujarat and Rajasthan); wind in the South (Tamil Nadu and Andhra Pradesh) and West (Gujarat); coal in the East and central West (Jharkhand, Odisha and Chhattisgarh); nuclear in the South, North and East (Karnataka, Andhra Pradesh, Jharkhand and Meghalaya); and hydropower in the East (Sikkim) (IEA 2014b). The difference in available resources influences the amount of power available within each of the regions. Those with insufficient resources have a power deficit, while those with large resources have a power surplus. On balance, India has been in power deficit for several years.

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**Figure 9. India's power grid regions**



*Note:* Map shows India's territorial claims

Source: IEA 2014b.

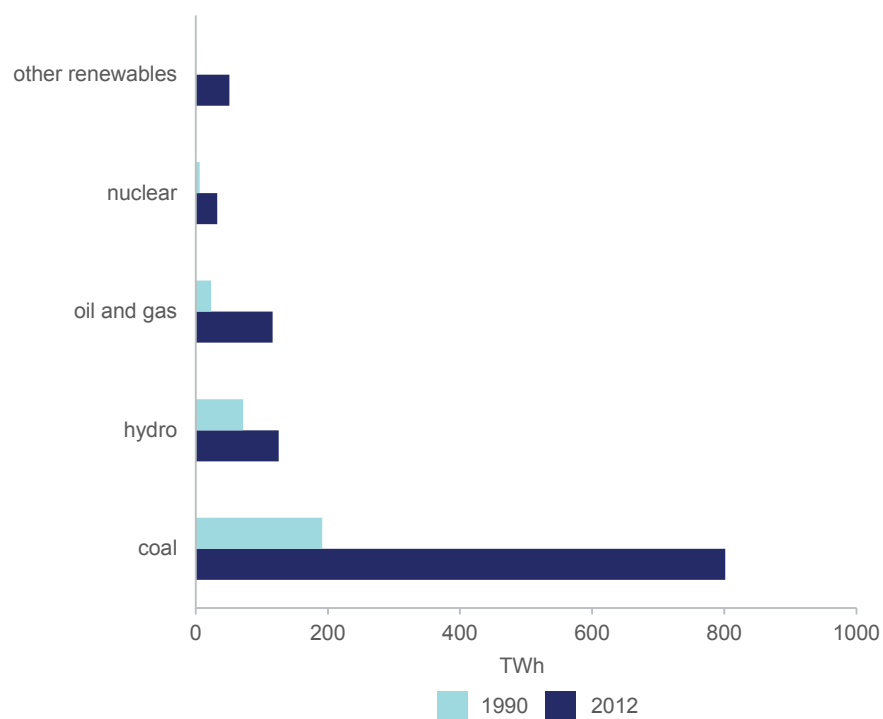
India's electricity market is principally powered by coal which accounts for almost three-quarters of total electricity generation (figure 10). India's coal-fired electricity generation more than doubled from around 390 TWh in 2000 to 800 TWh in 2012. In 2012, India had a total installed electricity capacity of around 250 gigawatts. Around 60 per cent of this was coal-fired. Other renewables accounted for 13 per cent of India's installed capacity, but only supplied 5 per cent of total generation, illustrating the relatively low utilisation and efficiency of these technologies (figure 11).

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*India's electricity market is principally powered by coal which accounts for almost three-quarters of total electricity generation.*

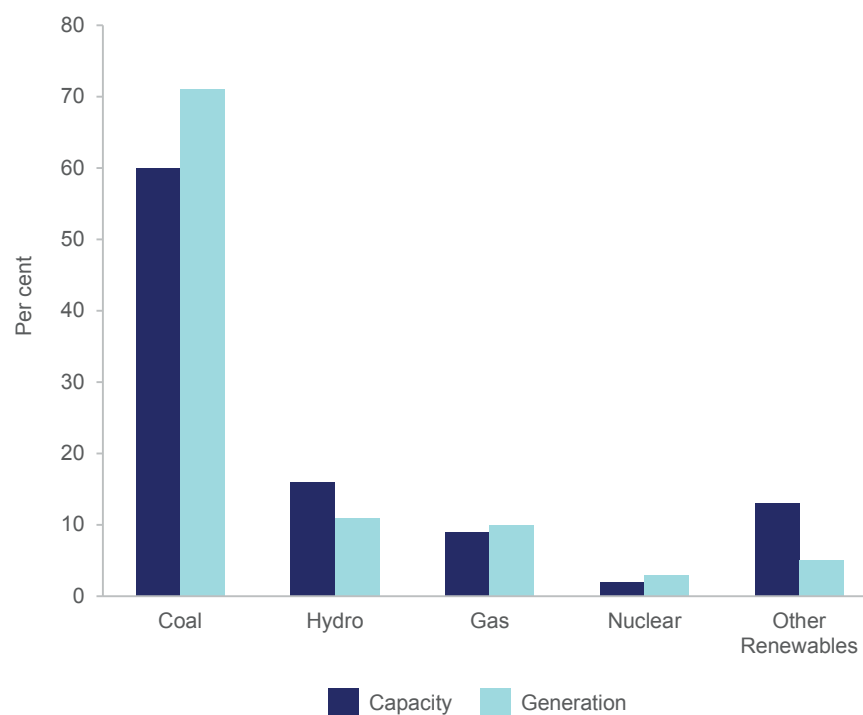
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**Figure 10. India's electricity generation**



Source: IEA 2014d.

**Figure 11. India's installed capacity and generation, 2012**



Source: Platts 2014; IEA 2014d.

Despite the rapid increase in electricity generation in recent years, supply has still not kept up with demand growth and India has not generated enough electricity to meet its requirements for many years. One of the main ways electricity distribution companies have managed this shortfall has been to load shed which involves cutting power to one part of the system so that the entire network is not overloaded. Distribution companies have tried to reduce the effect of load shedding through advanced warning so that consumers can plan ahead. However, it generally occurs during periods of peak use—5pm until 11pm (IEA 2014b). Load shedding is disruptive to business, industry, hospitals, schools and households that do not have access to electricity for the duration of the outage. Frequent or prolonged load shedding can reduce economic activity or be a deterrent to business investment. However, load shedding is typically directed to consumers that pay the least for electricity—the residential and agricultural sectors (EIA 2014).

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*Despite the rapid increase in electricity generation in recent years, supply has still not kept up with demand growth and India has not generated enough electricity to meet its requirements for many years.*

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## Challenges to India's electricity generation

### Electricity pricing

Electricity price subsidies are widely used in India. Industrial consumers are often levied with surcharges to subsidise other consumers, particularly agricultural users that do not pay for electricity. Most electricity sold to households is at prices below the cost of electricity generation. It is estimated that around 87 per cent of household electricity consumption is subsidised (Pargal & Banerjee 2014). Artificially low electricity prices do not send the appropriate signals for consumers to improve energy efficiency, alter their electricity use or stimulate investment (IEA 2014b).

Electricity in India is sold through a few different mechanisms, long term contracts, short term bilateral contracts and the spot market. Distribution companies purchase electricity from state generation utilities on long-term contract. These transactions account for the majority of electricity sales in India. The prices for these contracts are determined by regulatory agencies and are usually at cost plus a margin. The electricity price set by regulatory agencies in principle reflects fuel input costs. However, electricity pricing is politically sensitive and regulators are reluctant to increase prices too frequently or by too much. As a result, distribution companies often sell electricity at a loss which reduces the profitability of the sector (IEA 2012).

### Power theft

Power theft is a widespread problem in India, with some utilities claiming that up to 80 per cent of their power losses can be attributed to theft (Gupta 2014). The loss of revenue from theft reduces the finances available for maintenance of existing facilities and investment in new generation capacity.

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*Power theft is a widespread problem in India.*

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There are various methods of power theft; including illegally tapping into existing lines. In the most populous state of Uttar Pradesh, power theft is most prevalent through meter fraud and unmetered usage. Meter fraud



involves the payment of bribes to officials so that they will record a lower usage figure or tampering with meters using magnets. Excess unmetered use of electricity appears to be most common among agricultural consumers, who are not charged for electricity. It is estimated that agricultural consumers account for 25 per cent of total electricity consumption and are responsible for the bulk of the power sector's financial losses. Given the widespread and remote nature of some agricultural consumers is difficult to provide adequate metering systems to these areas (Golden & Min 2012).

A few Indian states have had some success in addressing the power theft issue. Kerala's power utilities have a reputation of excellent revenue management and have established 13 anti-power theft squads under the anti-theft and vigilance wing of the Kerala State Electricity Board (Pargal & Banerjee 2014). Gujarat has also been successful in combatting power theft especially relating to corruption through the introduction of legislation, the establishment of police stations solely focused on power theft and the widespread installation of meters (Wilkes 2014).

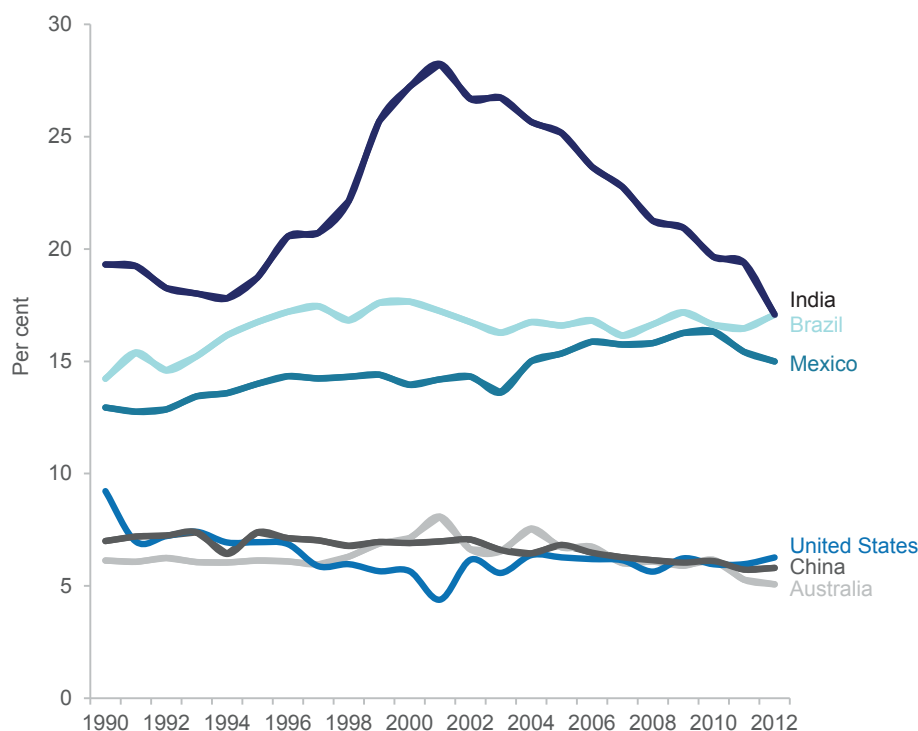
At a national level, the Indian Cabinet approved a US\$4 billion programme in November 2014 to roll out meters on distribution transformers, feeders and consumers in urban areas and strengthen sub-transmission and distribution networks initiatives. These measures are aimed at improving electricity access and limiting power losses through theft and any other means (Reuters 2014).

### **Transmission and distribution**

Although India has invested heavily in new electricity generation capacity, the same level of attention has not been directed to its transmission infrastructure which has contributed to the challenge of matching electricity supply with demand. Investment plans to increase transmission capacity have been stalled by delays in acquiring land, delays in scheduling and project delivery, a lack of best practice in project execution and insufficient private sector participation (IEA 2014b).

India's electricity grid has high transmission and distribution losses relative to the rest of the world. Even though losses have been declining, India's losses are estimated at between 21 per cent and 30 per cent nationally and up to 67 per cent in some states (figure 12). The national average is around three times the size of losses in China and the United States.

**Figure 12. Transmission and distribution losses, selected countries**



Source: IEA 2014e.

There are multiple reasons for India's electricity grid performance. From a technical perspective, grid losses primarily stem from insufficient investment in maintenance and system upgrades. This has resulted in an ad hoc approach to extended distribution lines and overloaded transformers and conductors. From a commercial perspective, these losses are the result of power theft (discussed above), inadequate metering and excess consumption in heavily subsidised sectors (IEA 2014b).

In the short term, transmission, distribution and commercial losses will affect the ability of the system to match supply and demand, which may have consequences for India's economic growth. Over the longer term, issues with transmission and distribution will also affect the ability of India to increase its reliance on renewable energy sources. Currently, India's new solar and wind capacity is not well integrated into the electricity grid. Slow timeframes for grid connection and poor grid management have adversely affected growth in wind projects and could present a barrier for the further adoption of solar photovoltaic (PV) (IEA 2014b).

There are plans underway to double the inter-regional transfer capacity of India's electricity grid. The MOP has also announced its intention to modernise India's electricity distribution system and improve data collection through the Restructured Accelerated Development and Reforms Programme.

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*India's power sector has been making large losses over the past several years.*

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## **Sector profitability**

India's power sector has been making large losses over the past several years. Profitability has been affected by regulated electricity pricing, power theft (as the sector is not receiving an income for the electricity generated), transmission and distribution losses, poor billing practices, consumers failing to pay and the misclassification of customers as subsidised users (IEA 2014b). A steep rise in the cost of inputs has also increased the cost of generation. Input costs have increased because of declining domestic fuel availability (which has increased the reliance on more expensive imports) and poor procurement planning, which results in distribution companies making last minute power purchases from the spot market which is typically higher cost than long-term contracts (Pargal & Banerjee 2014).

In 2011, the combined losses of the sector were around US\$10 billion, around 17 per cent of India's gross fiscal deficit and 0.7 per cent of its GDP. Sector losses are overwhelmingly concentrated in the distribution companies (Pargal & Banerjee 2014). Low profitability in the sector reduces the capacity of companies to invest in new capacity, improved efficiency and other vital infrastructure.

Losses in the sector have been financed through heavy borrowing, typically in the form of short-term loans, to ensure that companies can meet their operating expenses. This has resulted in a more leveraged (debt-financed) capital structure across the sector and an onerous interest burden. Persistent losses and rising debt burdens have reduced the creditworthiness of the sector, particularly distribution companies. In late 2011, many lenders withdrew finance from the sector. As credit availability declined, distribution companies were unable to pay for power purchases even when electricity was available to the market (Pargal & Banerjee 2014). As a result, many generators were failing to recover their operating costs and resorted to reducing output to well below capacity, creating supply problems (IEA 2014b). It has also slowed investment in new electricity generation capacity.

Should the sector continue to struggle with profitability, with flow on effects for the speed and scale of investment, it is possible that India will be unable to meet its ambitious expansion targets.

## **Regulation and project approvals**

India has often missed the electricity capacity expansion targets outlined in its Five-Year Plans (FYP). One of the greatest barriers to the development of electricity infrastructure (both generation and distribution) is the time required to obtain the relevant clearances. While these regulations have important functions in ensuring community rights and environmental protection, dealing with the relevant ministries is complex and at times politically and socially sensitive. More recently, infrastructure projects have been delayed by public protests and formal appeals through the legal system (IEA 2014b).

## Coal consumption

India is the world's third largest coal consumer behind China and the United States; and the share of coal in India's electricity mix has been rising. In 2013 India's coal consumption was estimated at 790 million tonnes (or 516 million tonnes of coal equivalent (Mtce), around 10 per cent less than the United States (IEA 2014f). Thermal coal accounts for around 85 per cent, or 665 million tonnes, of India's coal consumption. Metallurgical coal (80 million tonnes) and lignite (45 million tonnes) make up the balance.

The power sector accounts for more than 70 per cent of India's coal use and supported a five-fold increase in coal use in electricity generation over the past few decades. As such, the power sector is clearly central to the coal outlook in India. India's steel production has increased by around 25 per cent over the past five years to around 83 million tonnes in 2014. The cement industry, the second largest globally after China, is also a major coal user, accounting for around 5 per cent of total coal use. Other industrial sectors, including brick manufacture, consume small quantities of coal.

## Coal-fired generation

India has invested heavily in new coal-fired generation over the past few decades to support its rapid growth in electricity consumption (figure 13). The rate of growth in India's coal-fired generation capacity has accelerated since 2008 with installed capacity almost doubling in just six years. India's coal-fired capacity is located close to large demand centres with around 42 per cent of capacity located in the western region, 27 per cent in the north and 18 per cent in the south (figure 14). Unlike many OECD countries, India's installed capacity is relatively new and has many years of operational life remaining.

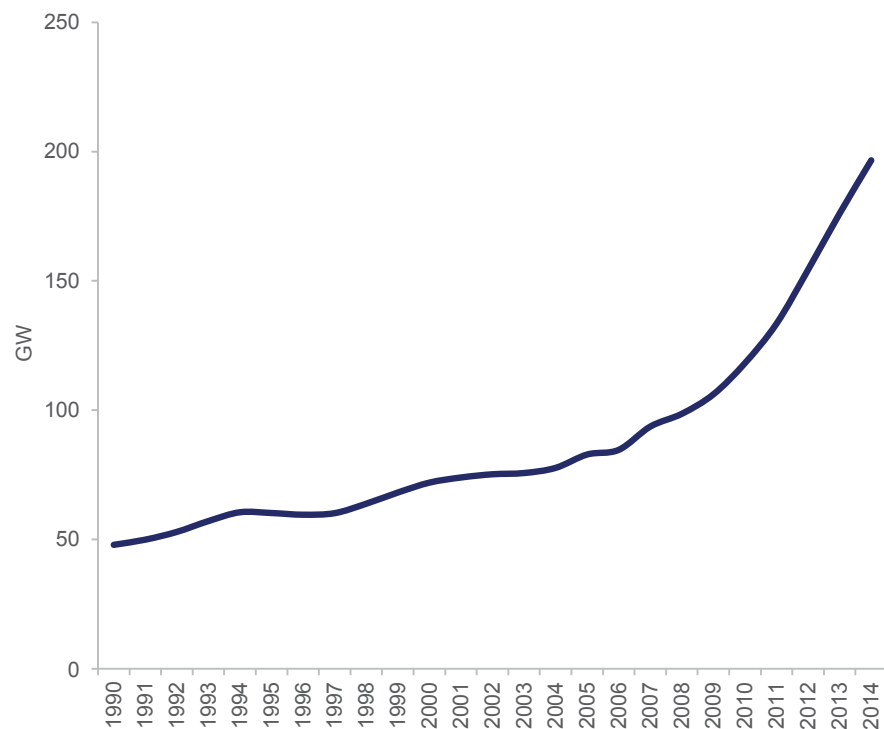
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*India has invested heavily in new coal-fired generation over the past few decades to support its rapid growth in electricity consumption.*

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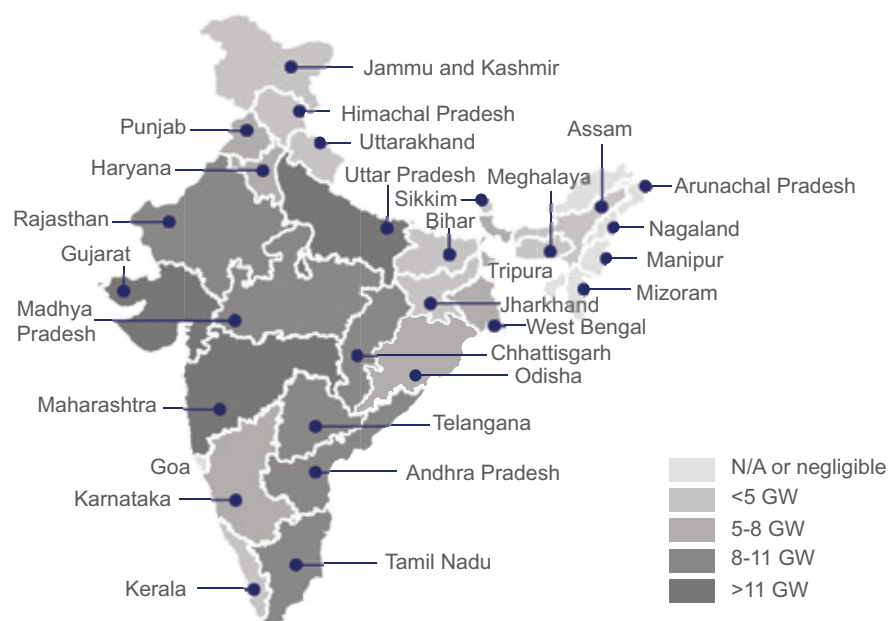


**Figure 13. India's installed coal-fired capacity**



Source: Enerdata 2015, [www.enerdata.net](http://www.enerdata.net).

**Figure 14. Installed coal-fired generation capacity of India's utilities by region, November 2014**



Note: Map shows India's territorial claims

Source: CEIC 2015.

Until 2010 almost all Indian coal-fired plants used subcritical technology, with an average efficiency of around 28 per cent, compared with 36 per cent in China and 33 per cent in the United States. Reflecting the relatively lower efficiency, the emissions from India's coal fleet are around 1100 grams of CO<sub>2</sub> per kilowatt hour, which is well above the most efficient plants at around 750 grams (IEA 2014b; IEA Clean Coal Centre 2014). In addition, the use of poor quality, high ash, Indian coal, while affecting the type of plants that have traditionally been built and hence efficiency, also reduces plant availability, as more frequent maintenance is required.

These factors have underpinned the targets in the Twelfth FYP (running from 2012 to 2017) to build large scale, more efficient supercritical plants. Furthermore, it is intended to use more efficient cooling technologies, avoid drawing on increasingly scarce inland water resources and use higher quality, low ash coal in order to maximise the efficiency gains, and raise plant utilisation, through higher coal availability and shorter maintenance times. This coal has tended to come chiefly from Indonesia, where several private power companies have an ownership stake in local mines.

The first supercritical plant in India was commissioned in 2012. It is expected that plants using this technology will account for an increasing share of new plants being developed—an estimated 40 per cent of new plants being developed over the current decade—as policy mandates their use beyond 2017. Nonetheless, the efficiency of Indian coal-fired power plants will remain well below global best practice, and subcritical plants will dominate the power mix for some time.

### *Box 2. Coal-fired electricity generation technologies*

Pulverised Coal Combustion (PCC) is the most common coal-fired technology deployed worldwide. There are a few PCC technologies being used that have markedly different efficiencies, costs and pollution outcomes. The efficiency of a plant refers to the electricity produced for a given heat input. In coal-fired power plants, this depends on the temperature and pressure of the steam generated in the boiler during combustion. The efficiency of a plant increases as both temperature and pressure are increased.

Subcritical technologies are the most common coal-fired plant utilised. It has the lowest efficiency (around 30 per cent) of the available technologies. Subcritical plants generally have low capital costs, which supports its large-scale uptake.

Supercritical technologies achieve efficiencies of around 40 per cent. The capital cost of these plants is higher because it must use materials with a greater heat tolerance in the boiler. Supercritical plants use less coal and generate less CO<sub>2</sub> than subcritical plants.

Ultra-supercritical and Advanced ultra-supercritical plants operate at efficiencies between 45–50 per cent. The capital cost of these plants is high because they must use advanced materials (with high nickel content) in the boiler. They use less coal and emit less CO<sub>2</sub> than supercritical plants.

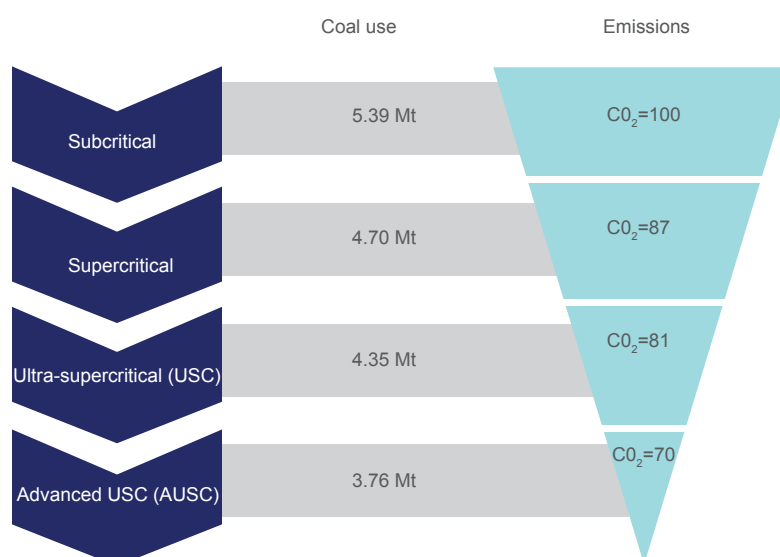
Plants that utilise supercritical technologies and above require higher energy coal, with low ash content, to operate optimally. See Appendix Part B for further details.

*The average efficiency of India's coal-fired power fleet is relatively low compared with other large energy users such as China and the United States.*

## Coal-fired plant performance

The average efficiency of India's coal-fired power fleet is relatively low compared with other large energy users such as China and the United States. The two underlying causes of this are the quality of coal used and the technical specifications of the generation fleet. Improvements in both areas could produce substantial improvements in efficiency and total output, while reducing carbon and particulate emissions per unit of electricity. Figure 15 illustrates the effect of different technologies on an 800 megawatt power station operating at a capacity factor (actual output relative to potential output) of 80 per cent and generating 6 TWh a year (IEA Clean Coal Centre 2014).

**Figure 15. Effects of different technologies on coal use and carbon emissions**



Source: IEA Clean Coal Centre 2014.

Note: Emissions are relative to a subcritical plant i.e a supercritical plant generates 13 per cent less CO<sub>2</sub>

India's domestically produced coal typically has a low to medium energy content, ranging from 2500 kilocalories per kilogram to 5000 kilocalories per kilogram (Australia's exports typically have an energy content greater than 5500 kilocalories per kilogram). The energy content of India's coal has been declining steadily over the past several decades as mines deplete their resources. The average energy content was 5900 kilocalories per kilogram in the 1960s, 4200 kilocalories per kilogram in the 1980s and around 3500 kilocalories per kilogram in the 2000s (IEA 2014b). This means that larger volumes of coal must be burned to achieve the same level of electricity generation and more pollutant emissions are generated.

According to the World Health Organization, six of the ten cities with the highest concentrations of PM<sub>2.5</sub> (particles less than 2.5 microns) are located in India. New Delhi has the highest concentration of PM<sub>2.5</sub>, with an annual average of 153 micrograms per cubic metre. By contrast, Beijing

has an annual average of 56 micrograms per cubic metre, almost a third of the levels observed in New Delhi (WHO 2014). Coal-use in power generation can contribute to PM<sub>2.5</sub>, but is not the main source. Motor vehicles, residential wood burning, forest fires, agricultural burning and some industrial processes can also contribute to PM<sub>2.5</sub> concentrations.

The high ash content and moderate moisture of Indian coal lowers its heating value and reduces the efficiency of its power plants. The high levels of silica in Indian coal also result in the ash by-product being highly corrosive. The corrosion makes the operation and maintenance of India's coal-fired fleet and the removal of ash more difficult relative to plants using higher grade coals.

The efficiency of a power plant is also affected by the temperature difference between the internal heat source and the external environment. India's high ambient temperatures and relative humidity are not consistent with achieving some of the efficiencies achieved in cooler climates such as in Europe. Coal-fired power plants in India tend to perform better in winter than in summer (IEA 2014b). Finally, around 90 per cent of India's coal-fired fleet utilises subcritical technologies that have substantially lower efficiency rates than the supercritical and ultra-supercritical technologies that have been developed and deployed in various countries (see Appendix Part B for more detail on these technologies). Moreover, much of India's older generators are smaller units with efficiency well below 30 per cent (IEA 2014b).

## Coal supply

### Coal reserves and production

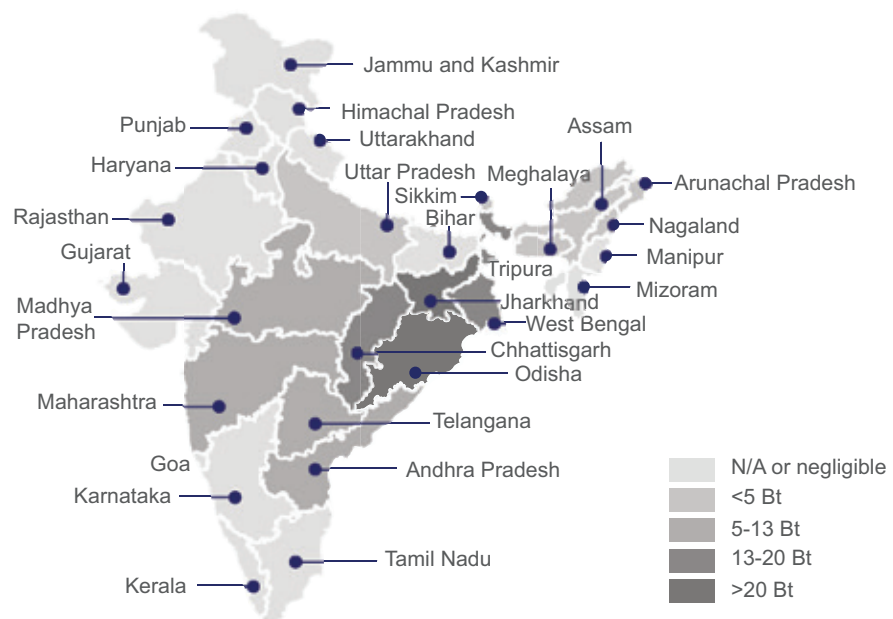
Coal is a key commodity in ensuring India's energy security because it is the most abundant non-renewable energy source in India. It has the world's fifth largest proved recoverable reserves of coal (60.6 billion tonnes) after the United States (237.3 billion tonnes), Russia (157.0 billion tonnes), China (114.5 billion tonnes) and Australia (76.4 billion tonnes) (WEC 2013). However, some experts have questioned whether these deposits are accessible given current technologies being deployed (IEA 2012). If reserves are overestimated, this could become a problem for production planning over the medium to longer term. Most of India's coal reserves are located in the east, with Jharkhand, Odisha, Chhattisgarh and West Bengal accounting for around 78 per cent of total proved reserves (figure 16). The distribution of India's coal reserves creates a supply challenge for India. The bulk of its coal resources are geographically separated from its principal areas of consumption and it requires substantial infrastructure networks to transport it from mine sites to generators.

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*Coal is a key commodity in ensuring India's energy security because it is the most abundant non-renewable energy source in India.*

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**Figure 16. India's proved coal reserves by region, 2014**



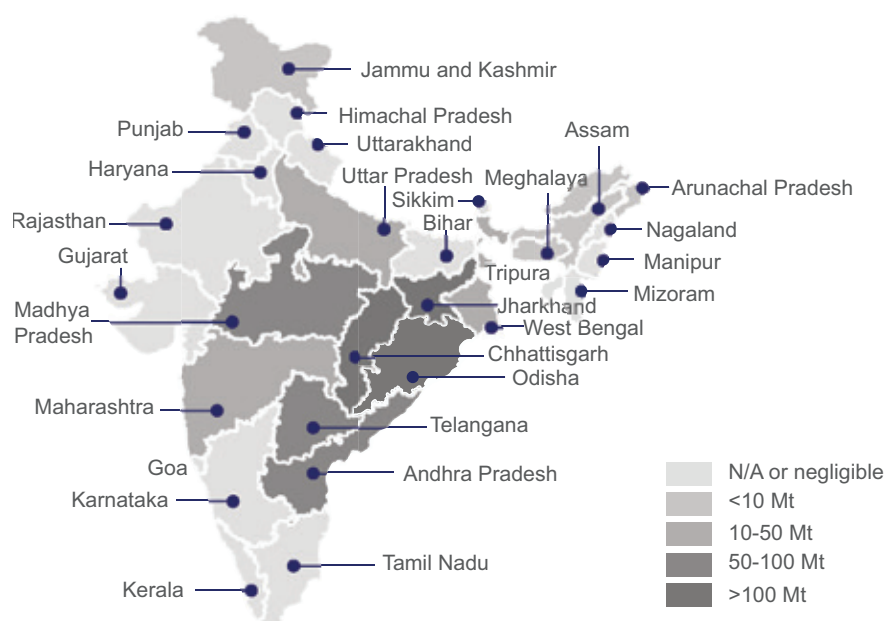
*Note:* Map shows India's territorial claims

Source: CEIC 2015.

Reflecting the location of its coal reserves, the majority of India's coal production is based in the east of the country (figure 17). Jharkhand, Odisha, Chhattisgarh and West Bengal account for around 65 per cent of India's coal production. A further 23 per cent of India's coal production is sourced from Madhya Pradesh and Andhra Pradesh.



**Figure 17. India's coal production by region, 2013**



Note: Map shows India's territorial claims

Source: CEIC 2015.

Coal quality varies substantially across India and the MOC classifies thermal coal into seven grades based on heat value, ash content, and gross calorific value (table 2, MOC 2014d). Indian coal typically has a low energy content compared with other internationally traded coals which typically have one-third to one-half greater energy content than average Indian coals. Indian coals also have high ash content (30 per cent to as much as 50 per cent), and low sulphur content. The moisture content of Indian coal is variable and is typically higher in coal produced during monsoon season (IEA 2012). Accordingly, Indian coal is generally unsuited for export, with higher quality imported coal often blended with domestic coal to raise quality and hence the combustion efficiency of India's coal-fired fleet. Alternatively, Indian coal is washed to reduce the volumes of impurities and improve coal quality. However, beneficiation (washing) capacity in India is limited and capacity utilisation is low (Bhattacharya et al 2013). Coal washing, identified as a key technology in the Eleventh FYP from 2007 to 2012, to improve efficiency and reduce pollution, fell far short of targets, with capacity only reaching 125 million tonnes a year, and washed coal production falling short of 50 million tonnes. In the Twelfth FYP from 2012 to 2017, thermal coal washing capacity is planned to reach 175 million tonnes.

*Coal quality varies substantially across India.*

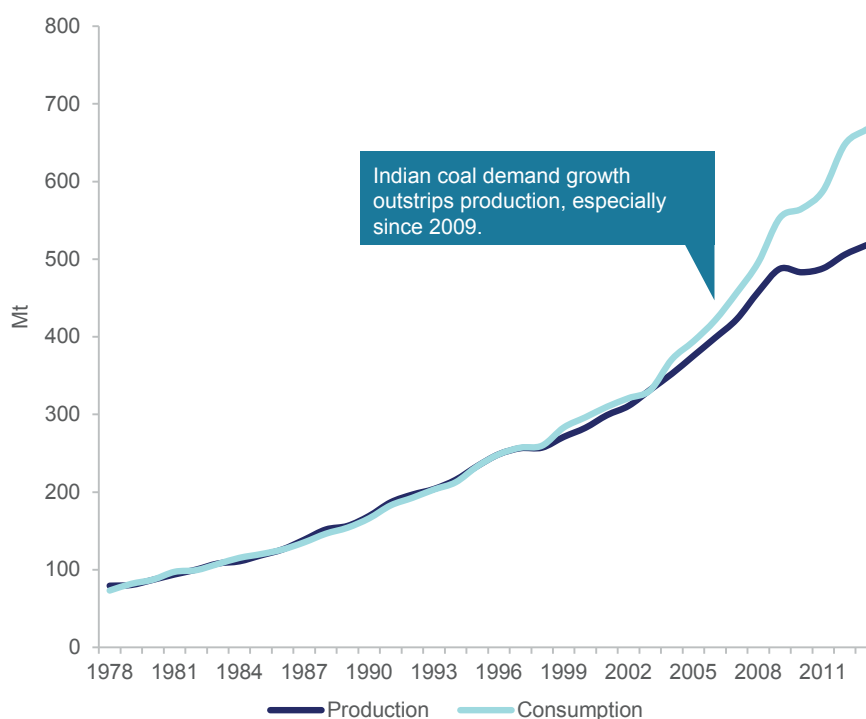
**Table 2. Indian thermal coal classification**

Grade	Useful Heat Value (UHV) (Kcal/ Kg) UHV= 8900- 138(A+M)	Corresponding Ash% + Moisture % at (60% RH & 40°C)	Gross Calorific Value GCV (Kcal/ Kg) (at 5% moisture level)
A	> 6200	<19.5	> 6454
B	5600–6200	19.6–23.8	6049–6454
C	4940–5600	23.9–28.6	5597–6049
D	4200–4940	28.7–34.0	5089–5597
E	3360–4200	34.1–40.0	4324–508
F	2400–3360	40.1–47.0	3865–4324
G	1300–2400	47.1–55.0	3113–3865

Source: MOC 2014d.

India is the world's third largest producer of thermal coal, well behind China and the United States. Despite large reserves, production growth has been well below growth in consumption in the past decade (figure 18). In response to the widening gap between India's coal consumption and production, imports of thermal coal have grown from 12 million tonnes in 2004 to 142 million tonnes in 2013.

*Despite large reserves, production growth has been well below growth in consumption in the past decade.*

**Figure 18. India's coal supply and demand**

Source: IEA 2014f.

India's thermal coal production increased more than six-fold between 1978 and 2009 in response to rapid growth in coal consumption in the electricity generation sector. However, the rate of growth in coal production has since slowed considerably. In general, the development of new projects has been stalled by difficulties in obtaining land access, environmental approvals and inadequate transport infrastructure.

CIL has missed its production targets for the last several years and its inability to meet domestic requirements is becoming one of the key dilemmas for India's energy policy. In 2013, India produced 518 million tonnes of thermal coal. CIL's production in 2014–15 (April 2014 to March 2015) was 3 per cent below its target of 507 million tonnes. CIL cited heavy rain, labour disputes and environmental laws as being the key reasons for missing the target (Dogra 2015).

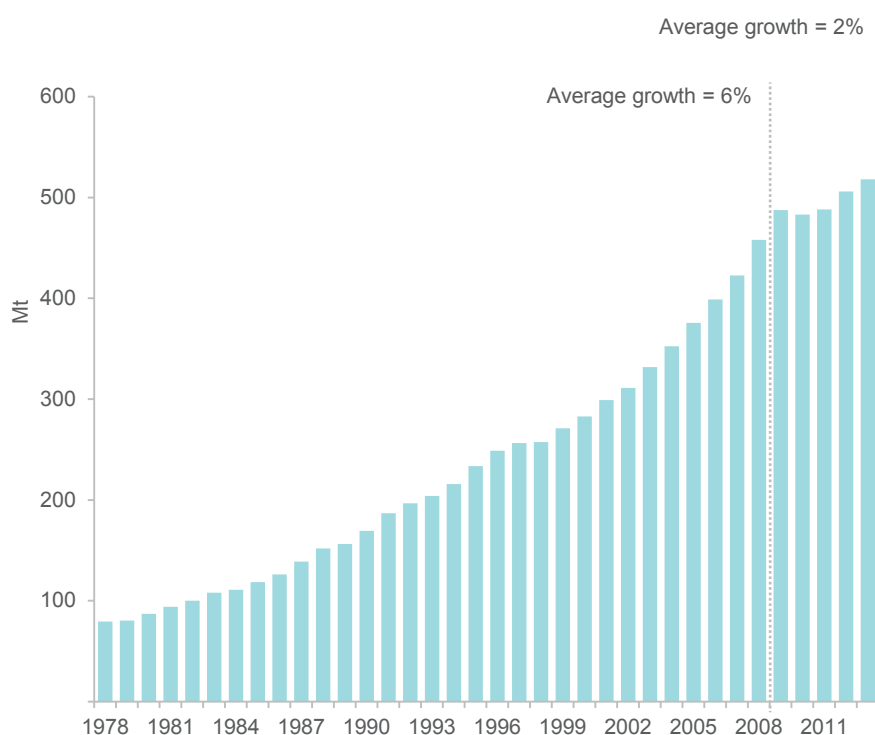
The average production growth rate is also declining. Over the period 1978 to 2008, production growth averaged 6 per cent a year. Since 2008 this has dropped to just 2 per cent a year (figure 19). The key issue for the government is to overcome this gap to the extent possible, through policy and other reforms, so that production can accelerate to keep up with fast growing power and industrial demand. The complex regulatory and institutional settings for India's coal industry will be significant challenges to achieving this outcome.

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*In general, the development of new projects has been stalled by difficulties in obtaining land access, environmental approvals and inadequate transport infrastructure.*

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**Figure 19. India's thermal coal production**



Source: IEA 2014f.

## Coal producers

### Government

CIL is the largest coal producer in the world. It accounts for around 80 per cent of India's total coal production and supplies coal to 82 of India's 86 coal-fired power stations. CIL supplies coal at a discounted price, relative to internationally traded coal, in an effort to protect generators from exposure to price volatility. CIL has been granted 'Maharatna' status which allows it greater autonomy over investment and other strategic decisions to expand the company without formal government approval (CIL 2014a).

The central government has a 49 per cent interest in a joint venture with the government of Andhra Pradesh called the Singareni Collieries Company Limited (SCCL). SCCL mainly supplies coal to southern India and accounts for around 10 per cent of India's total production. The Neyveli Lignite Corporation based in Tamil Nadu is also under the administrative control of the Central Government (MOC 2014c). The state of Gujarat has its own mining company, the Gujarat Mineral Development Corporation.

### Private

From 1976, public and private companies in key industries, such as steel-making, cement production and electricity generation, that required a stable supply of coal were permitted to operate coal mines. This production is referred to as 'captive' as it can only be used in approved activities and cannot be traded or exported. However, any surplus production can be sold to CIL (IEA 2012).

To expedite growth in captive production, the Indian Government allocated 218 blocks (land available for coal project development) for development since 1993. However, the allocation of these blocks did not result in a rapid increase in production for a number of reasons including the capacity of the successful applicants to develop mines and a very cumbersome process for obtaining land use approvals, and access to transport facilities. Of the 109 coal blocks allocated before 2007, only 28 blocks had commenced production by 2010–11 (Prayas Energy Group 2013).

In September 2014, the Supreme Court of India determined that the process for allocating captive coal blocks was arbitrary and illegal. As a result, 214 coal block licences were cancelled (World Coal Association 2015a). Around 46 of the blocks were open to two separate competitive auctions between mid-February and late March 2015 (Singh MP 2015). The auction process has raised large sums of money for the Indian government. As of late March, around 33 coal blocks had been auctioned for around 2 trillion Rupees (around US\$32 billion).

The government used a reverse auction process to sell coal blocks allocated to the power sector in an attempt to reduce fuel prices and keep electricity rates down. In this process, the bidder with the lowest quote below the

reserve price was awarded the block. The quote represents the company's base level cost to produce coal inclusive of taxes. They will be committed to produce a certain volume of coal or will incur financial penalties (much like take-or-pay arrangements for infrastructure). Because of strong competition for the available coal blocks, the government set the reserve price at zero. There has been concern that the aggressive bidding to secure blocks may make some of the projects unviable. However, it is not anticipated that the profitability of firms will be affected because the captive production will improve coal availability (some companies have not been operating because of inadequate coal supply) and reduce reliance on more expensive coal imports (Resource Digest 2015).

In March 2015, India's Parliament passed the Coal Mines (Special Provisions) Bill. The bill affirms that coal blocks will now only be allocated through auction to ensure transparency of allocation and secure large revenue streams to the states. It is expected that more coal blocks will be auctioned over the course of 2015. The bill also allows foreign companies with Indian subsidiaries or in a joint venture with Indian companies to develop coal deposits for own consumption or sale (World Coal Association 2015a). However, interest from foreign companies is expected to be limited because of a perception of excessive bureaucracy, lengthy approval processes and poor coal quality—companies would rather sell coal to India than develop Indian deposits. The appetite to invest in new projects has also been affected by low coal prices associated with global oversupply (Das & Paul 2015).

The experience and pedigree of the companies that are successful in obtaining coal blocks through the auction process will provide a good indication of whether captive production will be able to grow at a sufficient pace to meet India's growing requirements, and indeed whether the private sector can make the contribution anticipated by the government in raising coal output rapidly.

## Transport

The majority of India's coal-fired generation capacity is located in the northern and western regions of the country (figure 14). Only around 13 per cent of capacity is located in the eastern region where coal production is concentrated. As such, most of India's coal production needs to be transported long distances to get to its final destination, which has placed considerable strain on the infrastructure network. In 2013–14, around 55 per cent of CIL's production was transported by rail, 24 per cent by road, 19 per cent by merry-go-round and 2 per cent by other means (CIL 2014b). A discussion on the different methods of coal transportation can be found in box 3.

India's coal transportation systems have been challenged by the rapid increase in domestic demand. A shortage of rail infrastructure has stalled the movement of coal from domestic mines to power plants, and has contributed to the increased reliance on imports. While India's coal imports

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*The majority of India's coal-fired generation capacity is located in the northern and western regions of the country.*

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have increased rapidly over the past five years, India's capacity to continue to import large volumes of coal has also been affected by infrastructure limitations. During 2014, imports were affected by port congestion, particularly on the east coast; a shortage of rail wagons forced some companies to transport coal by road, which costs 30–40 per cent more; and inadequate logistics to move coal from port to utilities.

The transportation infrastructure challenge, particularly rail, is likely to be exacerbated as India's coal consumption grows. Growth in imports into coastal locations may relieve some of this burden. However, the demand for rail freight can only increase sharply as other modes of coal transportation have little potential for expansion.

### *Box 3: Coal transportation*

Once extracted, coal must be transported to its final end-user. For power plants located within close proximity to the mine or inaccessible by road, coal can be transported by **conveyor belt**, which reduces transportation costs. Conveyor belts generally transport coal between 8 and 24 kilometres. They are relatively low maintenance, but can be energy intensive and once built have limited location flexibility.

For power plants located further away from the mine, but still in relatively close proximity, coal can be transported by road in **trucks**. These trucks can have a capacity of up to 200 tonnes in some countries, but the capacity is typically lower in India. Where road is accessible, trucks provide the most versatile transportation option. However, loading and unloading can release large volumes of dust particles. In addition, truck loads are usually uncovered so there can be some product loss during transportation.

**Rail** is the most common form of coal transportation for long distances between mine and power plant or port. A typical train will have 100 to 120 carriages, with each carriage holding between 100 and 110 tonnes. The carriages generally can be emptied by turning them upside down, which reduces unloading times. Rail is typically more energy efficient than other systems, but is higher cost.

A **merry-go-round** is a dedicated shuttle train that operates between the mine and the power plant. The train can reverse direction without stopping, which allows it to load and unload its cargo while it is still moving and improve its efficiency.

Where coal mines are close to waterways, coal **barges** can be used to transport coal to end users. Typically a towboat will tow fifteen to forty barges; a jumbo barge can carry around 1200 tonnes. Barges can provide economies of scale and are typically cheaper than rail. However, they are restricted to waterways which can cause slower delivery.

**Ships** are most commonly used for international transportation. The most common ship sizes are: Handy Size (40 000 to 45 000 deadweight tonnes, DWT); Panamax (60 000 to 80 000 DWT), which is technically the maximum size for a vessel to pass through the Panama Canal (pre-expansion); and Capesize (more than 80 000 DWT), which is a vessel that is too large to go through the Panama Canal and needs to sail via the Cape of Good Hope from the Pacific to the Atlantic (Speight 2013).

## Imports

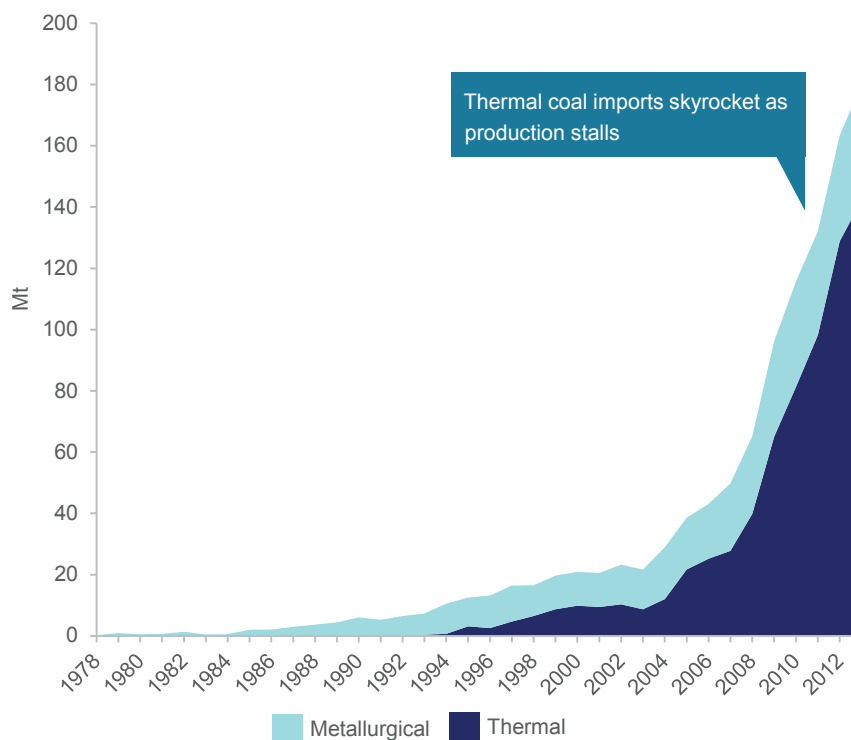
Until recently, India's domestic coal production was sufficient to meet consumption demand. However, the combination of rapidly increasing use and the recent downturn in production growth have underpinned an increase in India's coal imports. From 2009, India's imports accelerated both in volume and percentage of supply terms, increasing from 20 million tonnes to 180 million tonnes between 2000 and 2013, and now account for more than one quarter of Indian coal use. Thermal coal imports increased from 10 million tonnes in 2000 to 81 million tonnes in 2010 and 142 million tonnes in 2013 as India's production struggled to keep pace with demand (figure 20).

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*Until recently, India's domestic coal production was sufficient to meet consumption demand.*

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**Figure 20. India's coal imports**



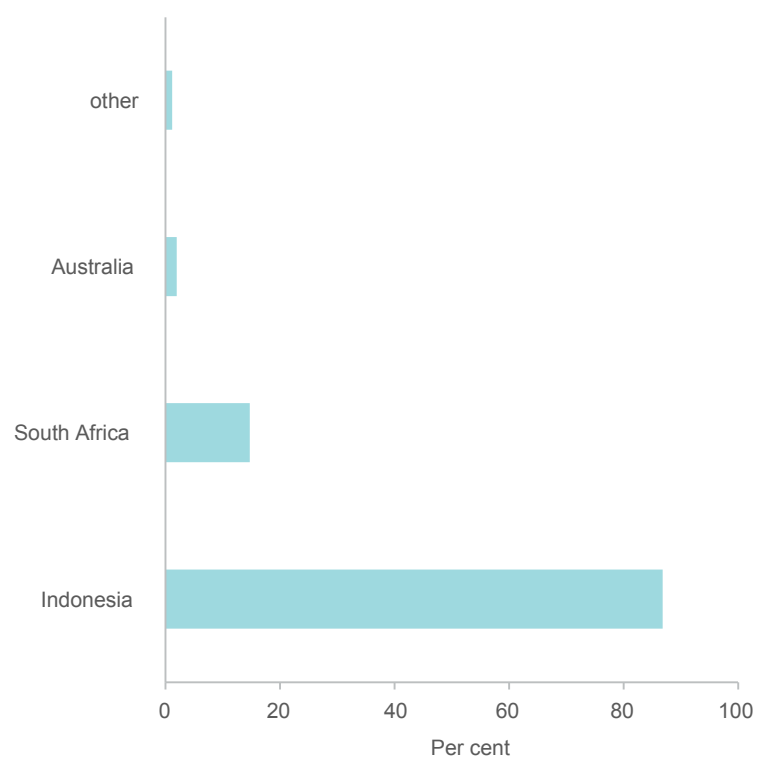
Source: IEA 2014f.

In 2005, India was around 90 per cent self-sufficient in coal supply. By 2013, India's coal self-sufficiency had declined to around 75 per cent, with thermal coal accounting for around 80 per cent of total imports. The rapid rise in thermal coal imports resulted in India overtaking Japan as the second largest importer of thermal coal in 2013 despite higher imports into Japan to help its electricity industry cope with the idling of its nuclear reactors after the Fukushima incident in 2011. In 2014, India's total coal imports (including both thermal and metallurgical coal) are estimated to have been around 200 million tonnes and on current trends will approach 250 million tonnes within a few years. While China's coal trade has been the driving force in international coal markets since it became a net coal importer in

2009, growth in India's coal imports is becoming increasingly important. So far, Indonesia has been the principal source of imports as the similarities in coal grade makes it easier to substitute into India's generator fleet while the low cost of Indonesia's coal has also made it more appealing to Indian buyers (figure 21). Smaller volumes of thermal coal are also sourced from South Africa, Australia, the United States, Colombia and Russia. However, the move to build generators that employ supercritical technology, which are run more optimally on higher grade coals, and moves by the government of Indonesia towards domestic reservation policies are two key factors that may alter India's import sources in the future.

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**Figure 21. India's thermal coal imports 2013, by source**



Source: IEA 2014f.





# Modi Government policies, reforms and impacts

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India is a federal republic, with significant powers vested in the 28 States, including water, land use, and mineral extraction taxes. The central government has powers over interstate trading, commerce, rail, and income tax. However, some responsibilities, such as electricity, are shared. This jurisdictional complexity contributes to the difficulties in introducing economic and policy reform in India. In addition, the emergence of multi-party coalition government in India over the past decade has impeded the government's ability to implement reforms. In mid-2014, Narendra Modi's Bharatiya Janata Party won India's strongest electoral mandate in 30 years on a platform of economic growth, lower inflation and job creation. Narendra Modi has a history of implementing reforms in the state of Gujarat. This has renewed optimism in the Indian economy and increased expectations that stalled capital projects might finally be developed.

An important first step to improving performance in the energy sector has been the appointment of a single Minister, Piyush Goyal, to oversee the Ministries of Coal, Power and New and Renewable Energy, where co-ordination and co-operation between the ministries have not been strong features. Between November 2014 and early 2015, the Modi Government announced a number of very ambitious policy and program targets over the next five to seven years to help achieve its economic, social and environmental goals. The Government's environmental goals are not currently targeting carbon emissions and are more focused on

the deployment of renewable energy technologies and improving energy efficiency. The plans for rapidly developing renewable energy do not signal a move away from coal; concurrently the Government has announced plans to almost double its coal output to one billion tonnes by 2020.

The Indian Government has frequently announced ambitious goals and reform plans, but implementation and delivery has often lagged behind targets. Expectations for the new government are undoubtedly high; the challenge will be to deliver on their ambitious plans. The opportunity for a policy led reform process to rapidly improve energy, economic and social outcomes in a major economy has never been greater, arguably since the reforms in China at the end of the 1970s. It remains to be seen if the new government can emulate that success.

## Economic development

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*The Modi Government has been under pressure to return India to a stronger economic growth trajectory.*

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The Modi Government has been under pressure to return India to a stronger economic growth trajectory. In response, it has been designing reforms and policies to promote growth. This includes the implementation of administrative reforms to reduce bureaucracy, reduce or improve approval times and expedite project development. In addition, the Finance Minister, Arun Jaitley, announced several measures in the Union Budget intended to promote growth and investment such as increased expenditure on infrastructure, tax incentives for savings and investment, and raising foreign direct investment limits in sectors such as railways (Modi 2015; Union Budget 2015).

As part of its growth objectives, the Government has plans to transform India into a new manufacturing hub through the Make in India programme. Make in India has been designed to facilitate investment, encourage innovation, protect intellectual property rights and develop world class manufacturing infrastructure. As part of this initiative, smart cities and industrial clusters are being developed in identified industrial corridors. There are five smart cities under development in the Delhi-Mumbai Industrial Corridor—Dholera, Shendra-Bidkin, Greater Noida, Ujjain and Gurgaon—and three industrial nodes in the Chennai-Bengaluru Industrial Corridor—Ponneri (Tamil Nadu), Krishnapatnam (Andhra Pradesh) and Tumkur (Karnataka) (Make in India 2015).

Following on from the Make in India programme, Minister Jaitley announced the Skills India programme in the 2014 budget. The programme intends to increase the employability of India's youth and address skills shortages that are limiting growth in India's manufacturing industries. India has a very young workforce, with more than 12 million new entrants to the labour market each year. However, only 2 per cent of these entrants have certified skills. This programme will include vocational training to develop the skills required in the manufacturing sector (Dhoot 2014).

Access to low-cost, reliable electricity will be fundamental to the expansion of India's manufacturing industry in order for it to be internationally

competitive. As India's economy develops, and the size of the manufacturing sector expands, growth in India's energy consumption is likely to accelerate.

## Energy and electricity

While the role of government-owned enterprises in India's energy sector has declined after a series of market reforms over the past two decades, central and state governments continue to exercise pervasive influence on it via policy settings and regulations. Historically, India's energy policy has been dominated by three major objectives: energy access, energy security, and reducing environmental impacts (through the deployment of renewable and energy efficient technologies). While such objectives are by no means unique, their context and implementation have taken on a uniquely Indian flavour.

It is estimated that around a quarter of India's population, around 300 million people, do not have access to electricity. This is clearly a major barrier to economic and social progress, and as such providing universal access has been a major priority for policy-makers. The Modi Government is progressing with plans to ensure adequate electricity supply, while acknowledging that in the short to medium term this may not be a continuous high quality 24/7 service, nor one based on grid interconnection.

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*It is estimated that around a quarter of India's population, around 300 million people, do not have access to electricity.*

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India has employed a series of Five Year Plans (FYP) to guide economic development (box 4). In the energy area, India's objectives in the FYPs have tended to be under-fulfilled. For example, during the period of the Eleventh FYP, ending in 2012, India's electricity capacity increased by 55 gigawatts. While an impressive increase in capacity, this was only around 70 per cent of the targeted 80 gigawatts. The current Twelfth FYP, which is scheduled to end in 2017, has a number of new features that differ from previous FYPs. It includes plans for greater participation by the private sector based on the development of several very large 4000 megawatt coal-fired power plants. These projects will use more efficient supercritical technology that will generally require higher-quality imported coal. The first of these projects, Mundra, was developed by Tata Power in Gujarat and has been in operation since 2012. Despite the use of advanced technology, the plants are still not optimised as they are configured to run on low-energy coal imported from the company's Indonesian mines (Tata Power has stake in PT Kaltim Prima Coal and PT Arutmin Indonesia) where it can secure coal at a low price (Kumar 2014).

In order for India to achieve increased electricity access, while meeting environmental goals, the wider roll-out of supercritical technology or better is essential. While more advanced technology is being introduced, progress has been slow. India's programmes to ensure that all new plants have efficiencies consistent with supercritical or ultra-supercritical technology are not expected to become effective until 2017 (IEA 2015). To this effect, around half of the coal-fired generation capacity likely to be commissioned during the Twelfth FYP is expected to be based on supercritical technology.

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However, this implies that the other half of new capacity will be based on subcritical technology, which is unlikely to be decommissioned before 2040.

#### *Box 4: India's Five Year Plans*

Like China, India's strategic planning for economic development is carried out through Five-Year Plans (FYP). The FYP contains targets, policies and programmes designed to achieve strategic economic objectives, such as health, education and the provision of infrastructure, over the duration of the plan. The targets need to be internally consistent to ensure the optimal use of the limited resources at the government's disposal. India's first FYP was launched in 1951; they are currently up to their Twelfth FYP, which is scheduled to run between 2012 and 2017.

The Planning Commission, now the National Institute for Transforming India, has been responsible for the development and implementation of India's FYP. The process has moved from being a technical exercise undertaken by the Commission to involving greater stakeholder participation as civil society becomes increasingly aware and vocal on issues regarding India's development. In the preparation of the Twelfth FYP, the Planning Commission consulted with central and state governments, sectoral experts and civil society.

As part of these plans, the Indian Government aims to attract around US\$250 billion of investment in the power sector over the next five years. There are currently major barriers to energy investment, such as price controls in the electricity sector, and very high losses between generation and consumption points. Some of this investment will be directed to improving transmission efficiency by improving the national power grid, and facilitating more widespread power sources such as solar and wind generation. This requires a substantial increase in foreign investment in India which will be challenging based on current foreign investor apprehension over market price controls, regulatory systems and exchange rate movements in India. State electricity distribution companies are a logical source for at least part of this investment, but their balance sheets and current financial position are unlikely to support expansions until price controls are relaxed and moves are made to reduce power theft from their networks.

### Climate change and renewables

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*Balancing economic growth (and subsequent increases in energy consumption) while limiting carbon emissions will be a significant challenge for India.*

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India is the world's third largest emitter of greenhouse gases; however on a per capita basis it is much lower down the world rankings at around 140. Balancing economic growth (and subsequent increases in energy consumption) while limiting carbon emissions will be a significant challenge for India.

Within the United Nations Framework Convention on Climate Change (UNFCCC) context, India, as an Annex II country, has no binding carbon reduction obligations. However, it has committed to reduce its carbon intensity (that is carbon emissions per unit of GDP) by at least one fifth from

2005 levels, by 2020. This does not imply that it will decrease its use of fossil fuels, but more likely that it will become more efficient in using them. For instance, the roll out of advanced coal generation technologies will deliver reductions in carbon emissions per kilowatt hour of electricity produced. Therefore carbon intensity could be reduced while overall coal consumption grows.

The total volume of India's emissions, although small in per capita terms, is likely to come under scrutiny in the lead-up to the Paris Conference of Parties (COP) at the end of 2015. In particular, India's INDC (intended nationally determined contribution), setting out its approach to greenhouse gas mitigation, will provide an important guide to the Modi Government's policies in this area. The release of India's INDC is expected in September 2015.

The Indian Government is heavily promoting the development of renewable energy technologies to achieve its environmental goals, including air pollution as air quality in cities such as Delhi is rapidly deteriorating. Some of the new and renewable technology being developed will be integrated into local or distributed energy systems, using battery storage and efficient end-use technologies such as lighting, to deliver power to more remote areas. In addition, direct use of solar power, in applications such as solar powered water pumps, where power storage is less of an issue, is also being encouraged.

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The Government has set a target to increase the installed capacity of renewable technologies to 175 gigawatts in 2022 (from around 65 gigawatts in early 2015). This is expected to comprise 100 gigawatts of solar, 60 gigawatts of wind, 10 gigawatts of biomass and 5 gigawatts of micro-hydro. To achieve this, there are plans to attract around US\$100 billion in finance to develop 16–18 gigawatts of solar and wind capacity a year. The development of solar photovoltaic (PV) is expected to account for around 10 gigawatts of this total. In achieving this target, India would need to match the pace of China's solar PV installation over the past few years and deploy 10–13 gigawatts each year.

To underpin these energy investments, the Indian government is introducing several measures to attract private investment through the taxation system such as a new 80 per cent accelerated depreciation allowance announced in May 2014. The Government is also encouraging the top 250 tax paying entities to utilise their strong balance sheets to build new renewable power plants and lower their tax liabilities through accelerated depreciation of their renewable assets. CIL and the NTPC are both cited as examples of entities that are involved, with CIL committing US\$1.2 billion to new PV.

If the solar target is achieved, power output, assuming a capacity factor of 25 per cent, could account for nearly 10 per cent of India's power generation by the middle of next decade. Rapidly falling solar panel costs, the relatively short lead times for installation, and the high value solar resource in many regions of India, make this plan appealing, but also undoubtedly very

ambitious. Globally, the levelised cost of electricity of solar power has fallen by around 40 per cent since 2010, as rapid rises in solar deployment, which increased ten-fold since 2008, allowed economies of scale in manufacturing, particularly in China. Following the pattern of other new technologies, further cost improvements can be expected. India's deployment of solar and wind power will face the continued problem of intermittent supply. Significant electricity storage capacity and flexible generation capacity will be required before such renewable energy sources can be treated as direct substitutes for fossil fuels.

The United States is supporting India's renewable energy drive, in the context of its support for its action on climate change and energy. In January 2015, the US-India joint statement on climate and clean energy co-operation was signed. The United States has pledged to explore funding options for the ambitious solar PV target in conjunction with the Indian Renewable Energy Development Agency. The Export-Import Bank is also exploring projects worth up to US\$1 billion. Further research on affordable solar energy, energy efficiency, and advanced biofuels is also part of this support.

## Mining and fuel supply

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*The rapid growth of coal imports has become a prime concern to the new government because of the perceived reduction in energy security.*

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The rapid growth of coal imports has become a prime concern to the new government because of the perceived reduction in energy security and the high cost of imports relative to local costs (although the higher energy content of imported coal offsets this to some degree). Minister Goyal has targeted a 15 per cent a year increase in CIL production, equal to a doubling of coal output to nearly one billion tonnes a year by the end of this decade. If this target is achieved, local output would be sufficient to meet rising demand (likely to grow nearly one third by 2020) and the need for imports negated. However, given the track record of recent production growth (less than 2 per cent a year), plus the necessity to speedily open new production areas, and build new transport links, this approach can be viewed as ambitious. A further challenge for India's domestic coal industry will be its ability to supply fuel for the more advanced coal-fired generators that are being rolled out. These generators are increasingly employing supercritical, or better, technologies that will operate optimally when fuelled with coal that has higher energy content and lower ash than most Indian coal mines produce.

The government has recognised that a key part of any moves to raise coal output will require increased private sector participation in the mining and sale of coal, but efforts to date have been hindered by the Supreme Court's decision to cancel existing captive coal block licences.

In October 2014, the government announced its intention to weaken CIL's near monopoly on mining and third party sales. In response, unions encouraged widespread industrial action in January 2015. Nonetheless, the MOC has announced plans to auction off 100 coal production blocks in 2015, with a further 100 in 2016. By 2020, it is envisaged that more than one third of Indian coal output will come from the private sector, or state governments. The government is also selling a further 10 per cent stake in CIL.



In order to promote a rapid increase in domestic production, proposals are underway to speed up environmental clearances, and land acquisition procedures. For example, it is proposed that procedures requiring approval of 70 per cent of landowners for land acquisition will be eased for certain corridors and mineral developments, but these proposals need Parliamentary approval. While the amendments to the Land Acquisition Act have passed through the lower house, the Modi Government has been unable to pass the legislation through the upper house where the opposition have claimed that the legislation impedes on the rights of farmers and the poor. The Bill may be referred to a joint committee to try and achieve consensus. Changes to pricing policies for coal are also designed to encourage more efficient mining, lower ash content, and investment in washing and beneficiation.

Reforms are also promised in the government-run rail sector, with plans for dedicated rail freight corridors, notably in the eastern corridor, which is important for coal movements. However, the cross subsidy between passenger and freight users, which keeps freight rates high, needs to be addressed. This subsidy can distort locational choices for coal-fired power plants, and favour plants close to mines, or on the coast using imported coal.



# Outlook for India's coal demand, supply and trade

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India's coal consumption has been growing at some remarkable rates in recent years. In the near term this is showing few signs of changing as investment in new coal-fired electricity generating capacity continues to grow at robust rates. In the longer term, how India responds to the international move to address climate change provides greater uncertainty in the outlook for its energy sector and coal market. This chapter reviews the projections for India's energy and coal use in the IEA's World Energy Outlook (WEO) 2014.

## The IEA World Energy Outlook

The IEA WEO provides three scenarios for long term energy use and the mix of sources that will supply it. The first is the Current Policies Scenario (CPS), which is essentially 'business as usual' and projects the trajectory for energy consumption and production based on economic, energy and climate change policies that are already in place. The second is the New Policies Scenario (NPS) which is the IEA's central scenario and takes into account announced policies that are yet to be enacted. For example, it includes policies announced by the United States to accelerate the decline of coal-fired electricity, which will take effect from



2017 at the earliest and announced measures by China to reduce local pollution and limit coal use. The third scenario, the 450 scenario, models a world where carbon emissions are limited to levels consistent with global temperatures increasing by just 2 degrees Celsius. This scenario outlines a set of policies and actions that would produce a trajectory of energy related greenhouse-gas emissions consistent with this international goal. In particular, carbon pricing is assumed to be widely adopted after 2020, although not in India.

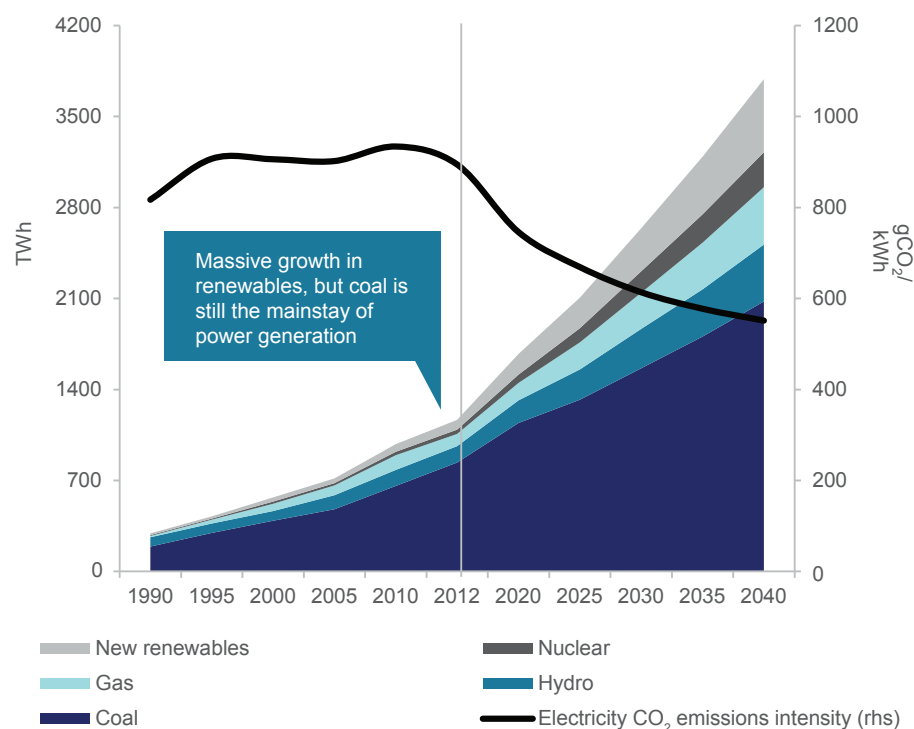
The IEA make a number of key assumptions for India that influence the projected results. In terms of macroeconomic indicators, India's GDP growth is assumed to average 6 per cent a year and urbanisation rate is assumed to be almost 50 per cent by 2040 (up from less than one-third today). It is assumed that India's population will increase by 0.8 per cent a year to 1.57 billion by 2040. India, already with a population larger than the OECD, is projected to overtake China as the most populous country early in the projection period.

The key policies in India that were included in the NPS were: the commitment to reduce CO<sub>2</sub> intensity by 20 per cent by 2020 compared with 2005; renewable energy support policies and targets; mandatory improvements in coal-fired plant efficiency; and the phase out of all fossil fuel subsidies by 2025. Other programs to enhance energy efficiency, including mandatory appliance standards, building codes, and industrial energy efficiency improvements were also modelled. In the 450 Scenario, carbon prices are assumed to become widespread, and be adopted in all OECD countries. While carbon prices are assumed to be gradually implemented in several major non-OECD countries, including China later in the projection period, they are not adopted in India.

## Electricity generation

The power sector is the key to understanding growth in India's thermal coal demand. In the IEA's CPS, coal-fired power increases to 2800 TWh, accounting for more than two-thirds of India's power demand of more than 4000 TWh by 2040. In the IEA's NPS, India's electricity generation is projected to increase at a lower, but still substantial, average annual rate of 4.3 per cent to 3787 TWh in 2040. While electricity generation is projected to grow, the emissions intensity of the electricity generation sector is projected to decline reflecting the increased share of renewable and nuclear technologies in the electricity mix, and an assumed increase in coal-fired power plant efficiency (figure 22). Nevertheless, coal use in India still increases in the NPS.

**Figure 22. India's electricity generation by source and CO<sub>2</sub> intensity, New Policies Scenario**



Sources: IEA 2014d; IEA 2014g; IEA 2014a.

India's electricity generation is projected to exceed 2100 TWh in 2025, which is more than the current output of Japan, South Korea and Australia combined. Reflecting the planned large-scale investment in renewable technologies, generation from new renewable sources is projected to grow rapidly, with wind and solar output tripling. Coal clearly remains the main power source, with output projected to increase by nearly 500 TWh, or more than the United Kingdom's current output. Therefore the relative share of coal in the electricity mix is projected to decline albeit with the use of coal still increasing substantially.

By 2040 the NPS projects that India's power generation will more than treble, growing at around 4.3 per cent a year, driven by steady population and economic growth. Nonetheless per capita power use is projected to remain low, at only around one-fifth of the OECD average, and universal access to electricity is by no means assured. Renewables, led by solar PV (forecast to grow to nearly 200 TWh or around Australia's total power output), wind and hydropower, are projected to account for 27 per cent of the electricity generation mix in 2040, from around 15 per cent in 2012. Gas-fired electricity generation is projected to account for 12 per cent of India's electricity generation. Nuclear generation is also projected to grow, especially post-2020, when annual capacity additions are targeted to reach 1.5 gigawatts. Despite progress in diversifying the generation sector, coal is projected to retain its dominant role, although its share will fall from almost three quarters, towards a little over half. In absolute terms coal-fired power

is projected to more than double in the NPS and increase at a rate of 3.3 per cent a year; from 840 TWh (roughly four times Australia's total power output) to nearly 2100 TWh.

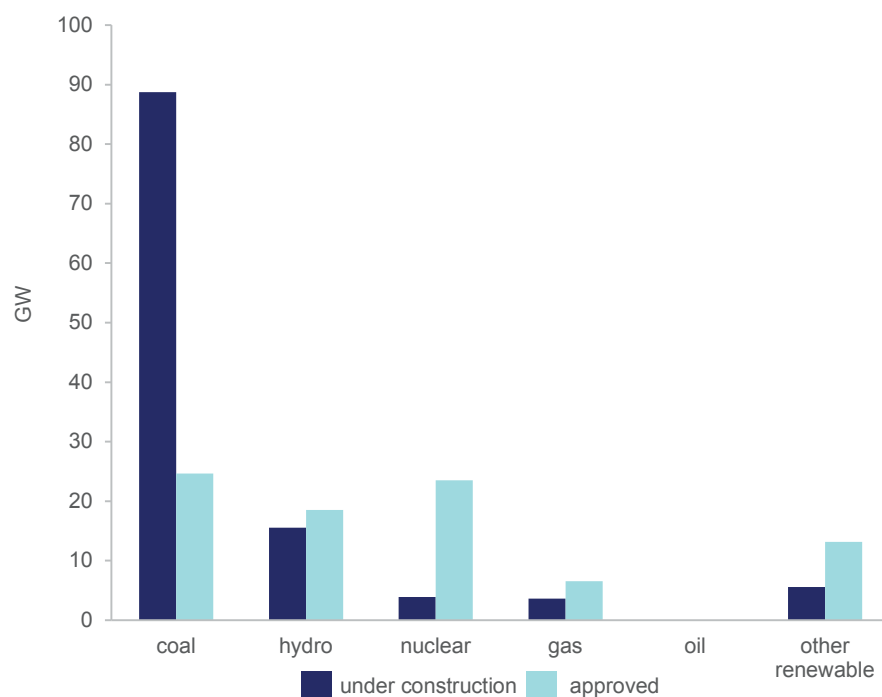
In the IEA's 450 Scenario India's total electricity generation grows by a slower, but still high, rate of 3.6 per cent a year with this lower rate underpinned by more stringent end use efficiency measures that reduce power demand growth. After increasing over the coming decade, coal-fired power is projected to decline, meeting only 18 per cent of power needs by 2040. Delivering this reduction requires some significant growth in other generating sources from current levels.

To achieve the 450 Scenario, India's nuclear power capacity would need to grow by a factor of 13 from its current level so that India operates a nuclear industry around the same size as France's current fleet (around 58 reactors with 63 gigawatts capacity). On average, India would need to start 2–3 nuclear reactors every year to deliver this by 2040. Hydropower capacity in India increases six-fold in the 450 Scenario from its current 42 gigawatts to 194 gigawatts in 2040. The availability of water as well as the distance of India's potential hydro schemes from key electricity consumption areas are likely to be significant challenges to overcome in delivering such an expansion in hydropower (UNEPFI 2010). Bioenergy increases by a factor of seven from a low base of 6 gigawatts in 2012 to 40 gigawatts in 2040. Wind power capacity would need to be expanded eight-fold from 18 gigawatts in 2012 to 141 gigawatts in 2040. Solar PV and concentrated solar power (CSP) would need to produce around 400 TWh in 2040 in the 450 scenario, double the already ambitious levels projected in the NPS and 200 times higher than currently produced (2 TWh in 2012).

Achieving the 450 Scenario for India would be exceptionally challenging. It would require a significant shift in government policy and very substantial and sustained investment in renewable technologies. The majority of these changes would need to occur rapidly in the period 2025 to 2040, as the majority of new plants (mostly coal-fired, figure 23) are either under construction or committed before that date. In addition, the premature closure of some relatively new coal-fired capacity would almost certainly be required to achieve this ambitious goal, further exacerbating economic costs and creating some uncertainty among investors.



**Figure 23. India's electricity generation capacity under development >50 MW**



Source: Enerdata 2015, [www.enerdata.net](http://www.enerdata.net).

## World coal consumption

Unsurprisingly, the IEA's three scenarios produce widely different outcomes for both world and India's coal consumption (figure 24). The differences between the three scenarios for coal demand are the largest for any fuel included in the WEO, reflecting the generally held position that the power sector must make the largest early contribution to decarbonising the energy sector, and that coal is the largest power sector fuel, and generally the most carbon intensive. In the 450 Scenario, global coal demand is projected to decline by a third, entirely after 2020; while in the CPS coal use increases by around 50 per cent. The range in outcomes highlights the difficulty with simultaneously addressing energy poverty and climate change. In emerging economies where coal dependence is high, the goals of improved environmental outcomes via reducing coal use, while extending and enhancing power supply to growing populations, will remain challenging.

There are wide regional differences in the IEA's scenarios which are indicative of the different energy needs of advanced and emerging economies. In the NPS, OECD demand, already barely a quarter of global coal demand and declining, is projected to fall by a third by 2040, while non-OECD demand is projected to grow by a similar rate. In the 450 Scenario, OECD coal use is projected to decline by more than half, while non-OECD consumption is projected to grow for a decade or so before declining to around three quarters of current levels. Even within the non-OECD group,

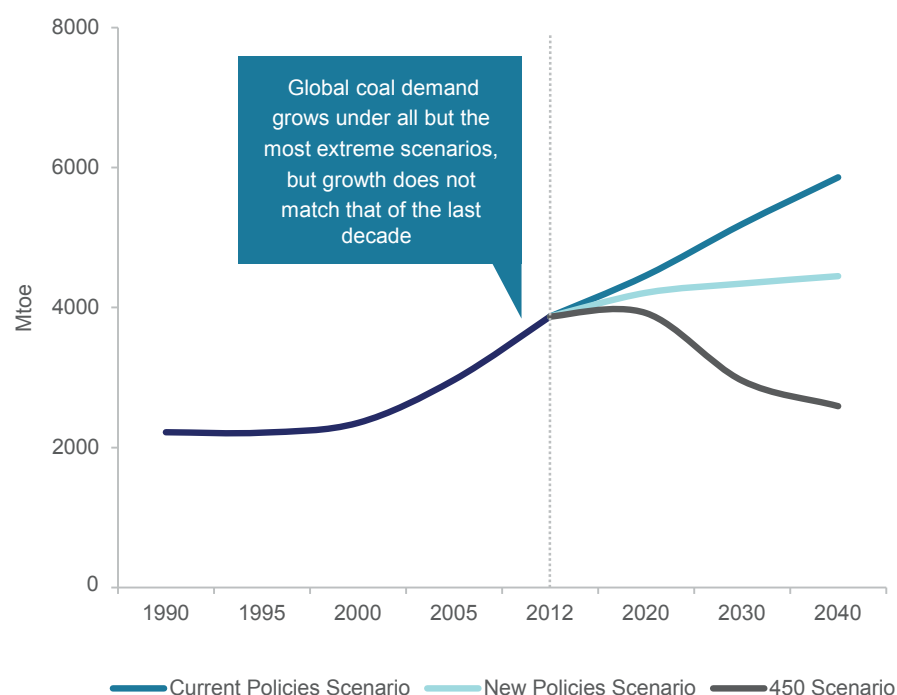
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*Unsurprisingly, the IEA's three scenarios produce widely different outcomes for both world and India's coal consumption.*

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the largest coal users are projected to exhibit differing trends. In the NPS, China, by far the largest coal user globally, is projected to continue to increase its coal use up to 2020 (albeit at much lower rates than in the last decade) before declining slowly over the last decade of the projection period. However, China's coal consumption in 2040 is projected to remain above 2012 consumption.

**Figure 24. World coal demand, by scenario**



Sources: IEA 2014d; IEA 2014a.

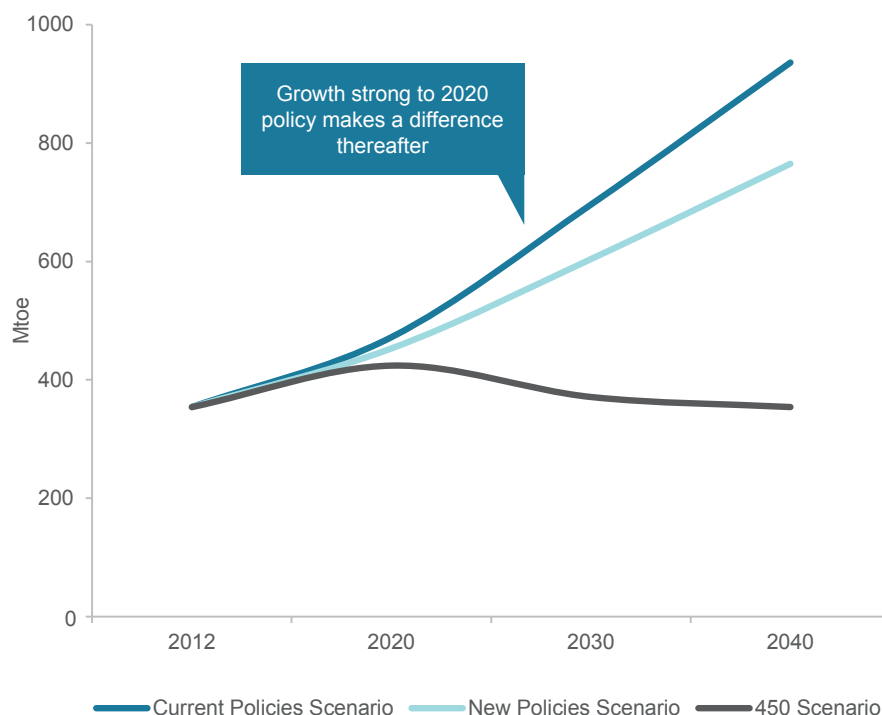
## India's coal consumption

In the NPS, India's coal consumption is projected to more than double, increasing at an average annual rate of 2.8 per cent, to 765 Mtoe. India is projected to overtake the United States as the world's second largest coal consumer before 2020, and remain the second largest consumer after China for the remainder of the projection period.

Investment in new coal-fired generation capacity already indicates that the 450 Scenario is unlikely for India. Furthermore, around 60 per cent of the subcritical coal power plants being developed worldwide are in India, these plants have lower efficiency and higher carbon emissions relative to other technologies. These and many recent investments are unlikely to be decommissioned by 2040 due to the economic costs and impact of a loss in generating capacity in a country targeting substantial increases in electricity consumption. The World Bank's decision to cease funding for coal-fired projects in developing countries, unless there is no feasible alternative,

is likely to stall the uptake of more efficient technologies that have higher capital costs unless other sources of finance can be organised. As a result, economies that are beginning to expand their coal-fired fleet are more likely to invest in cheaper subcritical technologies, which may contribute to increased emissions from the power sector.

**Figure 25. India's coal demand, by scenario**



Source: IEA 2014a.

Foreign Direct Investment (FDI) in India's power sector, previously capped, was reformed in 2013, allowing more FDI and with it newer technologies and higher efficiencies. As such, in the NPS, coal-fired power is projected to increase by two and half times, while coal use in the sector 'only' doubles. Demand growth is more rapid in the industrial sector, where efficiency improvements are less, but the sector still remains only a little larger than two fifths the size of the power sector in 2040.

The relatively slower growth in India's coal use is underpinned by an assumed increase in coal use efficiency. This will be supported by a number of factors relating to plant technology and coal quality. Over the past decade, around 90 per cent of India's coal-fired capacity has been based on subcritical technology. As outlined previously, an increasing proportion of new coal-fired plants are likely to employ supercritical technology and eventually ultra-supercritical technology. Over the short to medium term, it is expected that imported coal will continue to gain market share as larger, more efficient plants are built in coastal areas that require higher quality and lower ash content than domestic material to run optimally. For domestic-sourced coal, coal washing capacity and utilisation should increase, and

coupled with anticipated reforms to coal pricing and mining, should raise the quality of domestic coal output. These factors are expected to combine to raise the efficiency of India's coal-fired fleet from around 29 per cent to 36 per cent by 2040.

While coal is expected to dominate India's primary energy in the foreseeable future, it is exploring means of reducing the resultant emissions, including the use of carbon capture and storage (CCS). Current Indian CCS activities are at an early stage but include feasibility studies, capacity development, public acceptance studies, assessment of CCS for enhanced oil and gas recovery, research into advanced pre-combustion and post combustion technologies, and CO<sub>2</sub> utilisation using bio-industrial processes (TERI 2013; CCRI 2015). There appear to be two key barriers to implementation of CCS in India: 1) a lack of accurate geological data to adequately assess the location, capacity, permeability, and other characteristics of storage sites; and 2) the issue of CCS drastically increasing the cost of electricity while reducing net power output, which runs counter to India's ambitious goals for electrification, especially given the present electricity deficit and energy situation in the country (TERI 2013). Nevertheless, India is continuing research and development in the CCS and pursuing more cost-effective processes.

Notwithstanding relatively slow growth in global coal demand, and declines in imports in a number of OECD countries, including the European Union and Japan, the NPS projects inter-regional coal trade to grow by around 40 per cent in energy terms. Almost half of this increase is projected to occur by 2020, slowing later in the forecast period.

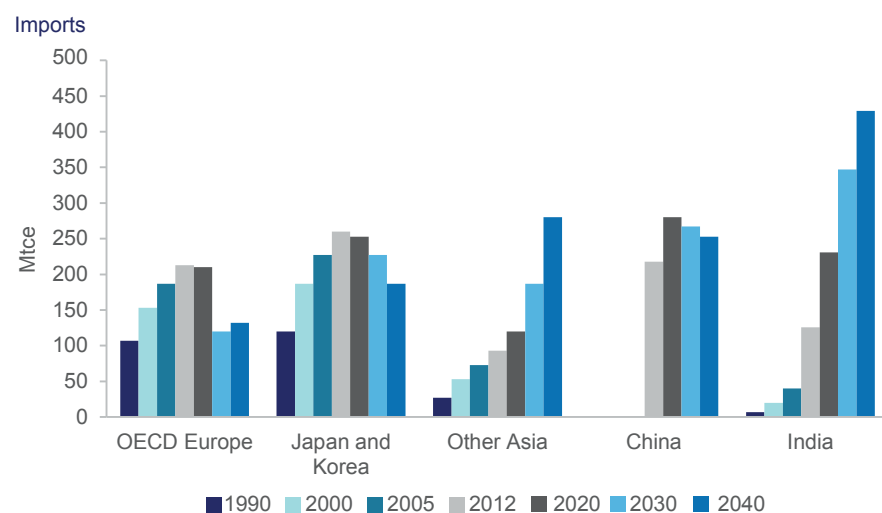
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*The conjunction of Chinese, Indian and other Asian countries' coal imports clearly shows the dominance of Asian markets in global coal trade over the projection period.*

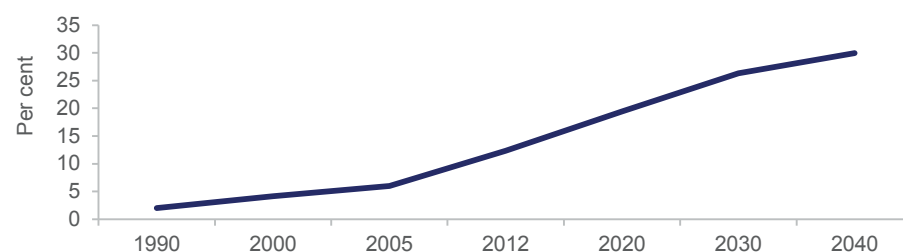
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Although the projected gains in India's coal production are impressive, India is projected to emerge as the world's largest coal importer, as soon as 2025, driven by the competitiveness and quality of imports in some coastal locations (figure 26). Over the projection period, India's share of the world's inter-regional trade is projected to increase from barely 10 per cent to almost one-third. Other Asian countries are also projected to emerge as major importers over the period to 2040, driven by rapidly increasing coal imports in Malaysia, Thailand, Chinese Taipei, Bangladesh and Pakistan, collectively reaching 290 million tonnes of coal equivalent (Mtce) by 2040, which is larger than China's projected imports at that time. The conjunction of Chinese, Indian and other Asian countries' coal imports clearly shows the dominance of Asian markets in global coal trade over the projection period.

**Figure 26. World coal imports, New Policies Scenario**



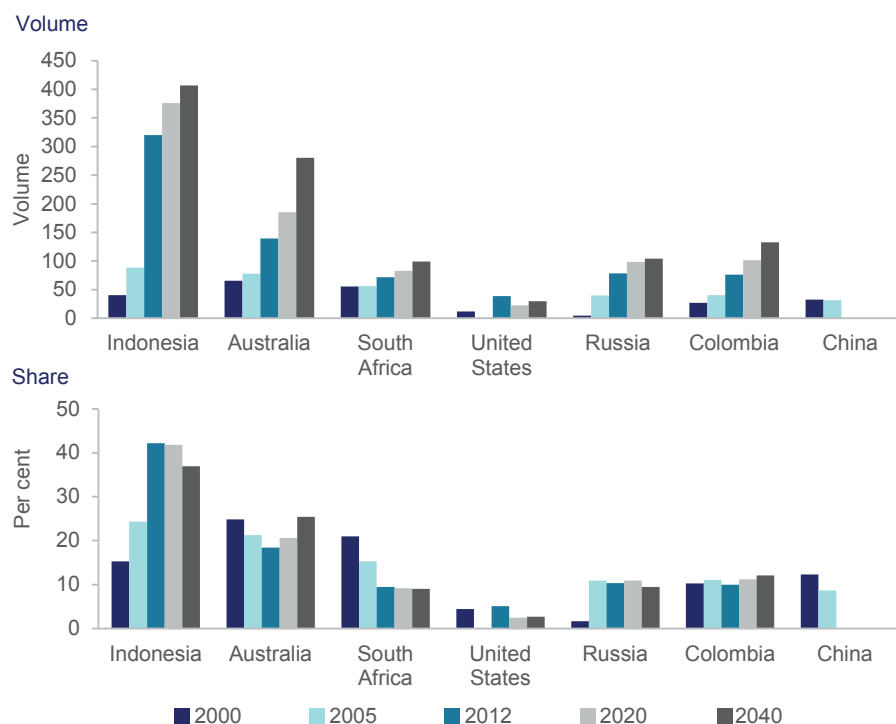
**India's share of world trade**



Source: Based on IEA 2014a.

In the NPS, the IEA expects Indonesia to remain the largest exporter of thermal coal with its exports increasing by more than a quarter out to 2040 (figure 27). The need to supply its own growing domestic energy needs and a move towards reservation policies are a key risk to this projection and may result in lower exports from Indonesia. Australia remains the second largest exporter of thermal coal in the NPS with its volumes rising to around 275 Mtce in 2040 to meet the growing needs for higher quality coal in growing Asian markets.

**Figure 27. Share of world thermal coal trade by type, New Policies Scenario**



Source: Based on IEA 2014a.

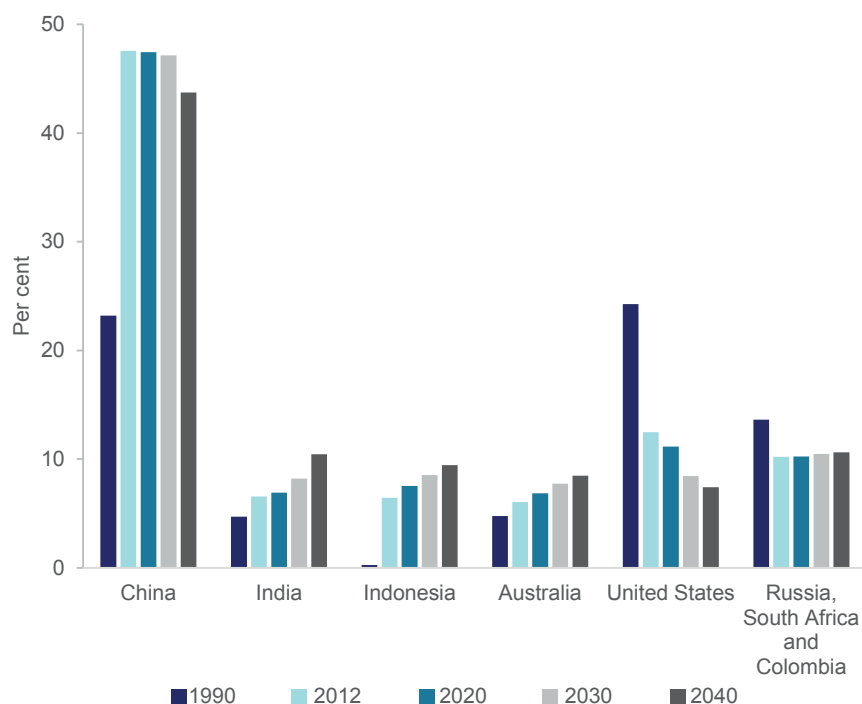
## World coal production

Eight countries account for 90 per cent of world coal production in the NPS, with China, India, Indonesia and Australia together accounting for 70 per cent of world coal production in 2040 (figure 28). World coal production is projected to increase by around 700 Mtce or the equivalent of coal production in the United States in 2012. Mirroring trends in coal consumption, most production growth is projected to come from non-OECD countries.

Non-OECD coal production is projected to increase by 20 per cent or 900 Mtce over the projection period. India and Indonesia are projected to account for 60 per cent of this growth. The combined production of India and Indonesia is projected to almost double over the forecast period. Both countries will overtake the United States by around 2030 to become the second and third largest coal producers, respectively. Indonesia is projected to become a large demand centre in the NPS, with its coal use projected to be equal to the European Union's current consumption by 2040. Consequently, a large proportion of Indonesia's increased production is likely to be directed to the domestic market.



**Figure 28. World coal production, New Policies Scenario**



Source: IEA 2014a.

## India's coal production

In India, domestic coal output is projected to increase by around 80 per cent in the NPS, with growth accelerating later in the projection period as anticipated reforms begin to take effect. As a result India's share of global output increases (figure 28).

Given the slow growth in domestic production over the past few years, the Indian Government estimates that it may need to import almost a third of its total coal requirements, or up to 350 million tonnes, by 2016–17 (CIL 2014a). Increased coal imports are likely to increase the cost of electricity, steel and cement, as imported coals, although of higher quality, are generally around two to three times more expensive on a weight basis than the price controlled domestic product. CIL has acknowledged that its future delivery obligations are likely to exceed its production capacity and has been investing in foreign coal assets to ensure stable supply to its customers. Its strategy to increase interest in foreign assets includes direct acquisition, equity participation, or long-term coal offtake arrangements. To date, foreign investment has been directed to Mozambique (CIL 2014a). However, it has been reported that this venture has not been as successful as hoped because the coal discovered in their Mozambique deposits has not met quality standards despite Indian power plants being configured to use low quality coal (Sengupta 2015a). CIL has also invested in South Africa's Limpopo Province, and was reportedly seeking Australian investments.

A number of private Indian companies have also been investing in foreign assets. There has been some interest in developing assets in the undeveloped Galilee Basin in Australia. The largest of these projects is Adani's \$16.5 billion Carmichael project. Once it has received all approvals, the project could consist of six open cut mines and five underground mines; a coal handling and processing plant; the development of water supply infrastructure; a 189 kilometre rail line; a worker's accommodation village and an airport (Department of State Development 2015). In addition, Indian infrastructure company GVK has been looking to invest in the Alpha and Kevin's Corner projects in the Galilee Basin. Adani has also developed mines in Indonesia to feed its private power plant in Gujarat, preferring to ship coal 6000 kilometres, rather than rail Indian coal 1500 kilometres. The investment includes port and rail facilities in India.

In order to meet the expected increase in India's coal consumption, and to reduce reliance on imports, the Indian Government set a target in late 2014 to roughly double India's coal production to one billion tonnes by 2020. To achieve this target, India will need to increase production by around 100 million tonnes each year, which would equate to an average annual production growth of almost 15 per cent a year. Given the average growth of less than 2 per cent a year over the past five years, meeting this target will be challenging. If all projects proceed as planned, it will still take several years before they are completed and operating at full capacity. India will also need to concurrently address infrastructure bottlenecks and expand its rail capacity so that production can be delivered to the areas where it is required.

## Challenges to India's production growth

### Productivity

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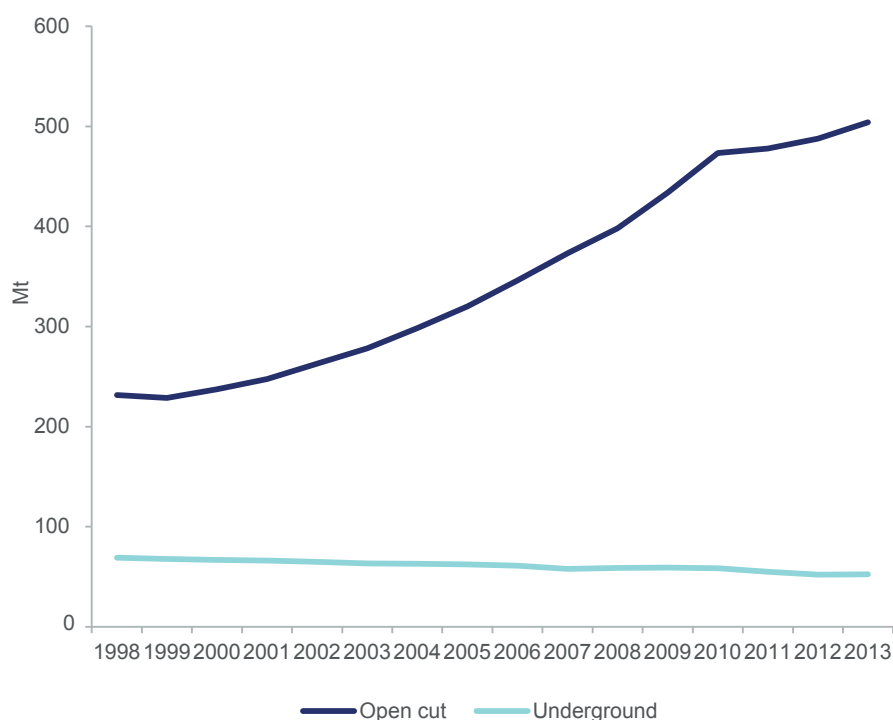
*The productivity of India's coal mines is low relative to international producers.*

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The productivity of India's coal mines is low relative to international producers. CIL produces 1100 tonnes of coal a year for each employee compared with Peabody's 36 700 tonnes and Shenhua Energy's 12 700 tonnes (Das & Paul 2015). This is largely the result of the use of older technology and production methods.

India's coal mines are typically at depths of less than 300 metres because of cost and technological limitations (IEA 2012). As a result, around 90 per cent of India's coal production is sourced from open cut mines (figure 29). Although there are hundreds of underground coal mines in India, they are small-scale and account for a very low proportion of total production. A large proportion of India's coal reserves are located at depths greater than 300 metres (IEA 2012). Consequently, increased adoption of underground mining and the introduction of more advanced technology could enhance access to its large coal reserves.

**Figure 29. India's coal production, by method**



Source: CEIC 2015.

Advanced technologies could also improve the productivity of existing operations. CIL has been engaging with foreign companies, including in Australia, to improve technology at their underground operations (CIL 2014b). Most of CIL's underground mines use the bord and pillar method, which leaves an estimated 40 million tonnes of coal in the mines each year. It is expected that through the introduction of continuous longwall mining at some operations that CIL can extract 70 per cent more coal from its existing and future operations. Improving recovery at existing operations could assist CIL in meeting India's proposed one billion tonne production target (Singh 2015; Press trust of India 2015; CIL 2014b). In further moves to improve its productivity, reduce costs and remain competitive against imports CIL announced plans to cut its workforce by 30 per cent (102 000 people). It is expected that this will be achieved through natural attrition—not replacing workers as they retire. These measures will only provide part of the required production growth and many new mines will be required to start production in the short term to achieve the production target.

### **Lengthy approval processes and coordination across ministries**

To develop a coal mine in India, project proponents need to acquire land, obtain multiple clearances, obtain environmental approval and in some instances resettle local communities. In addition, supporting infrastructure to transport the coal to end-users needs to be developed. This process requires input from multiple agencies across various levels of government and reflects the complex institutional structure outline in chapter 1 of this

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*The lengthy approval process has caused delays in new project developments and contributed to slow growth in production.*

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report. It has been estimated that more than 15 agencies are involved in the clearance process. This includes the Ministry of Environment and Forests, the Ministry of Coal, and the Coal Controller in the central government; and various state and local agencies such as mining, revenue, forest departments and the State Pollution Control Board (Prayas Energy Group 2013).

While there has been an increased focus on improving coordination, there are persistent issues with interagency interactions which contribute to extended timeframes for coal mine approvals. The lengthy approval process has caused delays in new project developments and contributed to slow growth in production. An audit report conducted by the Comptroller and Auditor General found that delays of between 1–12 years for 32 CIL projects resulted in lost production of almost 120 million tonnes (Prayas Energy Group 2013; Chatterjee 2010).

In terms of environmental clearance, delays stem from a lack of information of India's forest cover and biodiversity. Large areas of India have not been mapped and there is no database on areas considered to be ecologically sensitive or fragile. Accordingly, it takes an extended time for officials to assess applications for development (IEA 2014b).

## **Environmental and social issues**

While environmental legislation in India exists, compliance is reported to be low. Air and water quality in communities close to coal mines is poor, which can have flow-on health implications. The environmental lobby in India is very active and in some instances they have been successful in slowing land acquisition (IEA 2014b). The development of most coal projects requires the displacement of communities, which potentially has ramifications for the livelihoods of community members. Although policies regarding resettling communities exist, there are indications that in practice there remain problems in providing compensation. In some instances, affected community members are deemed ineligible for compensation and the remuneration for eligible members is often inadequate or delayed. Concerns about the environmental and social consequences of coal mine development may result in increased opposition to the industry in local communities (Prayas Energy Group 2013). Current approval processes generally require the agreement of at least 70 per cent of affected landholders. In a crowded and fragmented society such as India, this can prove a momentous hurdle.

## **Transport infrastructure**

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*The average cost of coal transportation in India is much higher than in other major coal producing countries.*

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The average cost of coal transportation in India is much higher than in other major coal producing countries. The cost of moving coal from mines in the east to major consuming areas such as Delhi, Mumbai or Chennai averages US\$17–19 a tonne, which is almost twice as expensive as moving coal the same distance in the United States (IEA 2014b). One factor underpinning this higher cost is the speed of freight trains in India which average less than 25 kilometres per hour (Pinto 2014). The Government committed to improve the speed of freight trains to 75 kilometres an hour in the 2015 budget.

As part of the plans to expand output to one billion tonnes, the short term priority for CIL is to develop three major railway lines to enable access to coal reserves in Jharkhand, Chhattisgarh and Odisha (Press trust of India 2015). These projects could be completed as soon as end 2017, and could free up as much as 300 million tonnes of mining capacity. The ability to modernise and extend India's coal transport infrastructure will depend on the availability of finance. The Government is intending to rely largely on public-private partnerships to fund required projects as internal sources are insufficient. The decision to open up the rail sector to greater foreign investment in the 2015 budget may facilitate this expansion, but foreign investors have been apprehensive to invest given past efforts. In order to attract foreign investment, the government may need to implement institutional reforms, such as the introduction of an independent rail regulator (Kazmin 2014).

### **Coal pricing**

Since 2012, India has been transitioning from a seven grade pricing system based on useful heat value to the much more common system internationally of gross calorific value. The change in pricing system is expected to provide the incentive to increase coal quality, particularly via coal washing. However, key customers have resisted its implementation, and as such slowed the benefits to be achieved through the transition.

In late April, CIL announced its intention to sell high quality coal at market-based prices so that it aligns with the price of international coal of a similar quality. Singareni Collieries Company Limited, another government-owned coal producer, has already implemented a similar system. Following the continued decline in world thermal coal prices over the past few years, the highest grade of coal sold by CIL is more expensive than imported alternatives. In part, the higher cost of CIL coal is attributable to high levies, which in some regions can account for around 60 per cent of the price of coal.

However, most Indian coal-fired plants cannot run solely on high quality coal. It is typically blended with lower quality coal at a ratio of 30 per cent high quality to 70 per cent low quality. While high-quality coal is currently more expensive than imported coal, the bulk of CIL's production is lower quality coal, which is around 30–40 per cent cheaper than equivalent imports (Sengupta 2015b).

Eastern Coalfields, a subsidiary of CIL, has put forward a proposal to increase the cost of its lower quality coal by 10 per cent. The proposal must be approved by the CIL board, and if approved is likely to be applied across all its subsidiaries (Sengupta 2015c). However, increasing the cost of lower quality coal is a sensitive topic as it will increase the cost of power generation, and many generation companies cannot afford an increase to their input costs without passing the additional cost on to consumers.







# Implications for Australia

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Coal has been one of the principal commodities that has underpinned Australia's latest mining boom. Australia's exports of thermal coal have increased by 132 per cent from 87 million tonnes in 2001 to 201 million tonnes in 2014. Similarly, metallurgical coal exports have increased from 106 million tonnes in 2001 to 186 million tonnes in 2014—a rise of 76 per cent. Over the same period around \$38 billion of coal mining and related infrastructure projects have been undertaken in Australia.

While the growth in Australia's coal exports has coincided with the substantial rise in India's coal imports, only exports of metallurgical coal to India have risen substantially (see table 3a and 3b). Australia is not a significant supplier of thermal coal to India despite India's imports growing by 84 million tonnes in the past five years. Thermal coal from Indonesia has met most of India's import growth while most of the growth in Australia's exports has been to China, Japan and South Korea.

**Table 3a. Australia's metallurgical coal exports by destination, Mt**

	2001	2005	2010	2011	2012	2013	2014
China	0.4	3.7	21.9	13.7	28.2	45.3	46.3
Japan	41.6	45.1	48.0	40.7	38.5	41.7	42.0
India	11.5	17.6	32.4	29.0	30.0	33.2	40.1
South Korea	6.7	10.5	17.4	16.2	15.8	17.0	20.4
Chinese Taipei	4.2	8.2	8.2	7.8	8.0	9.1	9.4
Other	41.8	39.8	31.1	25.2	24.2	23.6	28.2
Total	106.1	124.9	159.0	132.7	144.6	170.0	186.4

Source: ABS 2015.

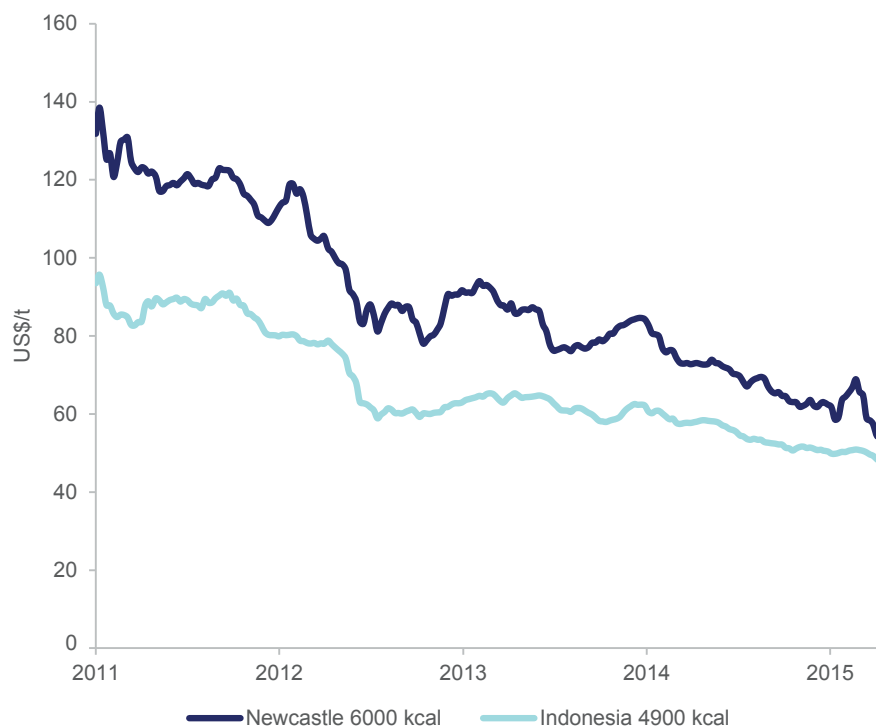
**Table 3b. Australia's thermal coal exports by destination, Mt**

	2001	2005	2010	2011	2012	2013	2014
Japan	50.1	59.5	69.8	65.4	75.2	82.3	77.7
China	0.8	1.8	14.5	19.9	34.3	42.5	47.1
South Korea	13.2	20.0	26.2	29.5	30.1	32.8	34.4
Chinese Taipei	8.8	13.5	20.5	19.1	16.4	18.0	20.5
India	1.4	1.2	0.4	1.2	2.1	1.7	6.7
Other	12.5	11.6	9.8	12.5	12.9	11.0	14.5
Total	86.7	107.6	141.3	147.5	171.1	188.2	200.9

Source: ABS 2015.

There are a range of factors that have limited Australia's thermal coal exports to India, particularly in the past five years. First, the price of Australia's thermal coal has exceeded the level that India's electricity companies, who are subjected to regulated prices, could profitably pay. Subsequently, India's coal importers have sourced supplies from the low-cost producers in Indonesia that supply lower energy content coal and have lower shipping costs for delivery to India. However, the energy content premium that Australia's coal typically attracts is getting smaller and key benchmark prices for Australian and Indonesia coal are getting closer (figure 30).

**Figure 30. Key coal price indicators**



Source: McCloskey 2015.

Second, is that the specifications of this lower cost coal from Indonesia are closer to that of Indian coal and more compatible with the engineering requirements of generators in India. The higher energy content and portion of volatile matter in Australian produced coal makes it unsuitable for many older subcritical generators in India that are not designed to operate at higher temperatures.

Third, is that there has thus far been very limited investment by Indian companies in Australian coal mines. While traders and utility companies can buy Australian coal openly on the market, doing so exposes buyers to market risks such as higher prices or lack of supply. Ownership of assets reduces exposure to these risks and improves the security of supply, which is an important feature for electricity companies that require a reliable source of fuel. Indian companies have accounted for a very small share of the massive inflow of foreign capital into Australia that occurred in the investment phase of the mining boom. By comparison, Indian companies have been investing in mines in Indonesia and, more recently, Mozambique. For example, Adani commenced coal mining operations at the Bunyu coal mine in Kalimantan in 2008 and produces around 5 million tonnes of thermal coal for export to India each year. While this project has provided Adani with a reliable source of coal for its electricity generators in Gujarat, it also provides economic benefits to Indonesia in the form of foreign direct investment, government royalties and around 1300 jobs for local residents.

### *Box 5. Indian investment in the Galilee Basin*

The Galilee Basin is an undeveloped coal basin in western Queensland that, if developed, could become the largest coal-producing region in Queensland. The proposed projects in the region are expected to attract more than \$28 billion in investment and create more than 15 000 jobs during construction and 13 000 jobs once operational (Department of State Development 2014). There is strong interest from Indian companies in developing projects in the Galilee Basin. These companies will control the full supply chain, including mine, rail and port infrastructure.

Adani's \$16.5 billion Carmichael coal mine and rail project is the most advanced project in the region. At full capacity, the mine will be capable of producing up to 60 million tonnes of thermal coal a year. The complex will consist of six open-cut pits and five underground mines; five mine infrastructure areas; a coal processing and handling plant; workers accommodation; an airport; and water infrastructure. Adani is also developing 189 kilometres of rail to transport the coal to a newly expanded coal terminal at Abbot Point (Adani Mining 2013; Department of State Development 2015).

GVK has plans to develop the Alpha (in partnership with Hancock Coal) and Kevin's Corner projects. Alpha will be a 30 million tonnes a year thermal coal mine, consisting of four open-cut pits, with the potential to expand underground in the future. GVK will also develop a 495 kilometre rail line to transport coal from the mine to Abbot Point. The Kevin's Corner project will be a 30 million tonnes a year open-cut and underground mine. The project will also include a small rail component (18 kilometres) to link to the Alpha rail infrastructure (GVK 2010; 2011).

Most of the coal produced from these projects is expected to be destined for export markets, primarily India, although the potential to supply the domestic market is also being considered.

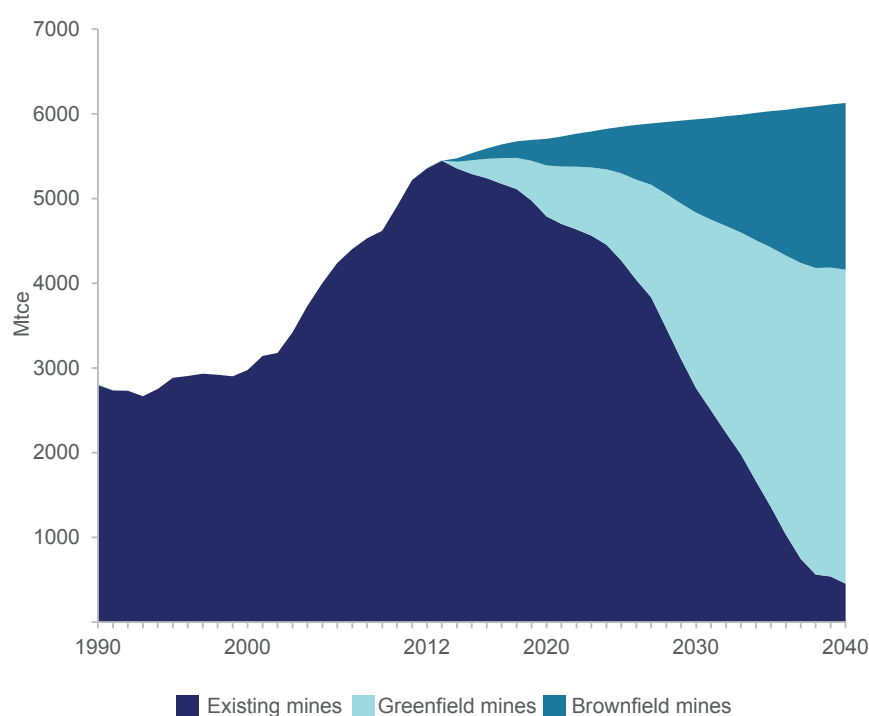
Although prices, coal quality and investment have thus far limited growth in Australia's thermal coal exports to India, these barriers are now starting fall. While coal consumption in Asia-Pacific markets that Australia supplies is still growing, the rapid growth in the availability of supply has driven benchmark Australian thermal coal prices lower. Australian producers are successfully implementing cost reduction and productivity improvements programs which combined with a weaker Australian dollar have made Australian coal more competitive in international markets. Although the volume growth was small, this was reflected in Australia's thermal exports to India increasing nearly 300 per cent to 6.7 million tonnes in 2014.

This report has highlighted that much of India's coal fired electricity generator fleet still employs subcritical technology that burns at lower temperatures. Australia's coal, with high energy content, will remain unsuitable for use in these generators though still potentially useful for blending with some of the lower grade coals produced in India to raise the average energy content per tonne of coal consumed. However, India's investment in new generating capacity has a greater share of generators that employ supercritical technologies to provide better thermal efficiencies and lower carbon emissions per gigawatt hour of electricity produced. Electricity output from these generators will be optimised by using higher energy content coal

with lower ash levels than most of India's domestic mines produce. Australia is not unique in supplying world coal markets with higher grade coal, but the roll out of advanced coal generator technologies presents a significant long term opportunity for Australian coal producers.

Investment by Indian coal companies in Australia has thus far been largely limited to metallurgical coal assets. However, the development of greenfield mines in the Galilee Basin in central Queensland may alter this if they proceed to construction. As highlighted by the IEA, greenfield coal mine development remains essential over the long term to offset the depletion rate of existing mines around the world (figure 31), even as coal demand growth slows sharply from the levels seen in recent years. Adani's Carmichael mine and GVK's Alpha mine are two advanced projects that are proposed for development in the region and signify the intent of Indian companies to invest in politically stable jurisdictions that can provide long term reliable supplies of coal to meet the growing energy needs of India.

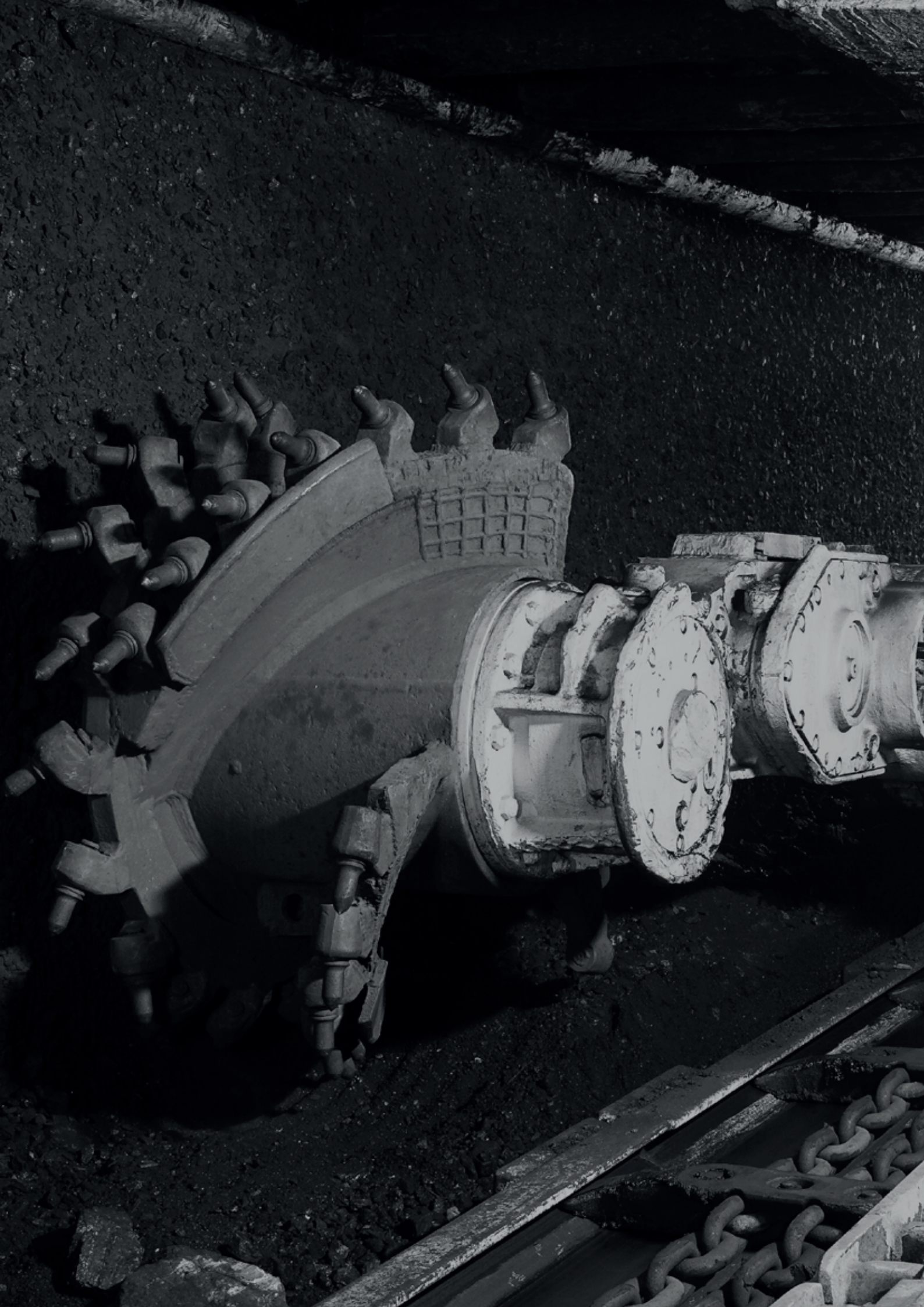
**Figure 31. Projected coal production by deposit type**



Source: IEA 2014a.

India's desire to improve the productivity of domestic coal mines through advanced technology may present an opportunity for Australia's mining equipment, technology and services (METS) sector. METS and oil, gas and energy resources (which includes coal) have been identified as two of the five industry growth centres by the Australian Government as part of its Industry Innovation and Competitiveness Agenda. The Indian Government, through CIL, has already expressed an interest in working with Australian companies to upgrade the technology employed in their coal sector.







# Appendix—Coal fundamentals

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Coal has underpinned global electricity generation and industrialisation for over a century. While the world is consuming more coal as it progresses into the 21st century, the industry has come under increasing scrutiny over the past few years because of its perceived environmental impacts. While there is no doubt that coal use generates carbon emissions, what is often misunderstood is the extent to which emerging coal-fired technologies can contribute to abating emissions; and the challenge that removing all fossil fuels from the world's energy mix will pose while billions of people in emerging economies increase their consumption of electricity. The purpose of this appendix is to review the characteristics of coal resources, mining and coal-fired electricity generation technologies that have been referred to in the main body of this report.

## Part A—Coal properties and extraction

### Uses of coal

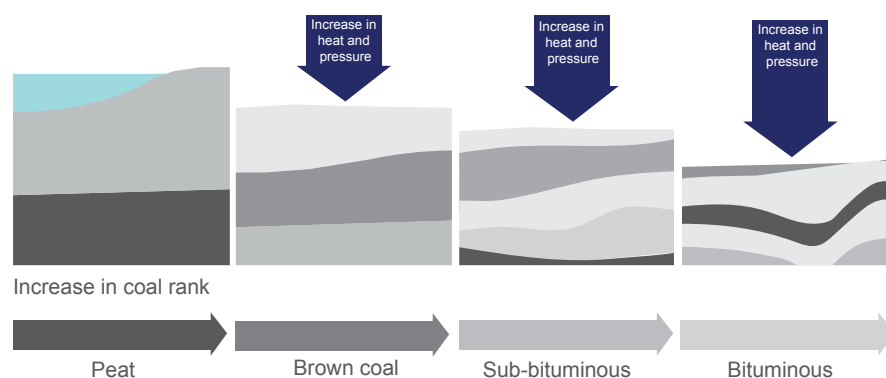
The main uses of coal are electricity generation, steel production, cement manufacturing and as a liquid fuel. Coal is classified into two categories; thermal coal and metallurgical coal, based on its qualities and end use. Thermal, or steaming, coal is mainly used in electricity generation and cement production. Metallurgical, or coking, coal is mainly used in steel production. Metallurgical coal is typically higher grade and has fewer impurities than thermal coal.

## Coal characteristics

Coal is a combustible rock that is composed mainly of carbon, hydrogen and oxygen. It is formed over time when plant material is covered by layers of silt and other sediments that prevent it from completely decomposing. As the plant material is buried it becomes exposed to high temperature and pressure which cause physical and chemical changes to the material resulting in coal seams. These seams can range in thickness from millimetres to tens of metres (Geoscience Australia and Bureau of Resources and Energy Economics 2014).

The quality of the coal is determined by the pressure, temperature, purity and length of time in formation. Coal ranges from lignite or 'brown coal' to anthracite (figure 32). Lignite is relatively soft and its colour can range from dark black to varied shades of brown. Over the course of millions of years, the coal matures and becomes harder and blacker (World Coal Institute 2009).

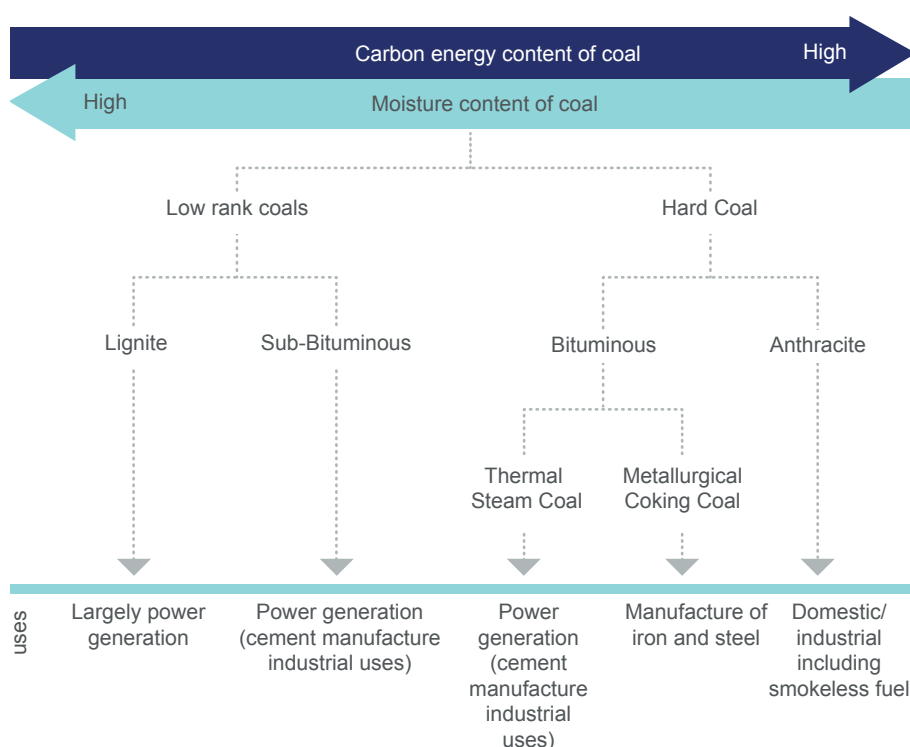
**Figure 32. Coal formation**



Source: Geoscience Australia and Bureau of Resources and Energy Economics 2014.

The length of time that the coal has taken to develop determines its physical and chemical properties, or 'rank'. Lignite and sub-bituminous coals are referred to as 'low rank' coal. They are typically softer, easy to break-down into smaller pieces and have a dull appearance. They usually have high moisture content and lower carbon content which adversely affect their energy content. Conversely, 'high rank' coals (bituminous and anthracite) are harder, stronger and lustrous. They have low moisture content and high carbon content which means they can produce more energy per unit of consumption (figure 33).

**Figure 33. Types of coal**



Source: World Coal Institute 2009.

Coal is not a standard product and even coal from a single seam can vary in quality. Coal formations have different physical and chemical properties that affect its overall energy content and efficiency in different applications. The quality of coal has a major influence on the design of a power plant, as well as its operation and performance (Miller 2013). When determining the quality of coal, several properties are considered. These include: energy content, volatile matter, sulphur, moisture, ash and trace elements.

## Energy content

Energy content is the most important property for determining the effectiveness of coal in power generation. It represents the amount of energy that can be produced by burning a given quantity of coal. In a power plant, the energy content determines the volume of coal needed to achieve a desired level of electricity generation. The higher the energy content, the lower the plant's coal requirements. Most coal-fired power plants are configured to use coal with specific energy content, measured in kilocalories, megajoules, or million tonnes of coal equivalent (the energy generated by burning one tonne of coal, it is the equivalent to burning 700 kilograms of oil).

As outlined above, the carbon content, and therefore energy content of coal, increases over time. Accordingly, lignite has the lowest energy content, while anthracite has the highest average energy content. The energy content of

lignite varies between 2200–4600 kilocalories per kilogram; sub-bituminous between 4700–7200 kilocalories; bituminous between 6100–8300 kilocalories; and anthracite between 7200–8300 kilocalories (Bowen & Irwin 2008).

Volatile matter refers to the components in coal that are released in the early stages of combustion. This usually consists of combustible gases such as methane and hydrogen located in the pores of the coal. Coal with large amounts of volatile matter ignite easily; burn quickly; burn with a long smoky flame; and generally has a lower heating value (Speight 2013).

## **Sulphur**

The sulphur content of coal is an important consideration in coal utilisation because it can contribute to increased air pollution. When coal is burned the sulphur contained in the coal forms sulphur dioxide, which can contribute to the formation of acid rain. It can also combine with soot particulates to cause smog. Smog can have detrimental health effects and is becoming a major problem in some highly populated cities in emerging economies, particularly China and India. The smog haze that is generated in these cities is often incorrectly attributed to carbon emissions; however the two are not necessarily related as measures can be undertaken to reduce the sulphur emissions that cause smog.

To reduce the effect of sulphur on air quality, coal with low sulphur content can be used. Some sulphur can be removed from coal prior to its use through beneficiation (see discussion on coal preparation below). However, washing increases the cost of production and can only remove 'pyritic sulphur'—sulphur combined with iron to form pyrite or 'fool's gold'.

When sulphur cannot be removed from the coal, it can be removed from the post-combustion gases before they enter the atmosphere using flue gas desulphurisation units, or 'scrubbers'. The scrubbers spray a mixture of limestone and water onto the combustion gases, which attach to the sulphur and form either a wet paste or a dry powder that can be captured (DOE 2013). The sulphur content of coal ranges between 0.6 to 4.0 per cent (Bowen & Irwin 2008). Australian coal is typically low in sulphur.

## **Ash**

Despite the name, coal does not contain ash. Ash refers to the non-combustible material contained in coal that becomes a by-product of coal combustion. The ash content of coal can range between 3–50 per cent (Bowen & Irwin 2008). Australian coal is typically at the lower end of this spectrum and is usually washed prior to export. Washing reduces ash and improves the overall quality of the coal.

Ash can combine with other elements to line the boiler, which affects the operation of the plant, reducing its efficiency and resulting in expensive repairs (Speight 2013). Higher ash can also increase the operating expenses

of a power plant because of the costs associated with removing, cooling and transporting it (Sargent & Lundy 2009). The ash content of coal can be reduced through blending—mixing with coal that has lower ash content—or through washing as described below.

Ash is typically composed of silica, aluminium oxide, iron oxide, calcium oxide, magnesium oxide and sodium oxide. When coal is combusted, the resulting ash is classified as either ‘fly ash’ or ‘bottom ash’. Fly ash is a fine, powdery substance that rises with the combustion gases. The ash that does not rise is collected at the bottom of the boiler as a molten slag and is referred to as bottom ash. Ash has several end-use applications including concrete production, cement clinker production, waste stabilisation and solidification, mine reclamation and other industrial and agricultural uses (Speight 2013).

In early 2015, China imposed restrictions on local production and imports of coal with high ash content (greater than 40 per cent). Tighter restrictions were imposed on coal being used in highly populated areas including Beijing, Tianjin and Hebei; The Yangtze River Delta in the east (which captures Shanghai); and the Pearl River Delta in the south (Guangdong). Coal in these regions must have ash content lower than 16 per cent.

## **Moisture**

Most coals contain some moisture. A large proportion of this can be removed by heating the coal at relatively low temperatures to dry it out. The efficiency of a boiler is reduced when coal has high moisture content because the water is vaporised during combustion and the associated heat is not recovered. As such, the heat used to vaporise the water reduces the amount of heat available to generate steam in the boiler (Sargent & Lundy 2009). Moisture also adds weight to the coal, which increases the cost of transportation.

## **Trace elements**

Coal can contain traces of other elements including antimony, arsenic, boron, beryllium, bromine, cadmium, chlorine, cobalt, chromium, copper, fluorine, iodine, mercury, manganese, molybdenum, nickel, lead, selenium, thorium, uranium, vanadium and zinc. These trace elements can be left behind in the ash and have adverse environmental and health effects when combusted. The Australian coal industry is striving to minimise its environmental footprint, there are strict environmental, health and safety laws that must be met.

## **Coal resources and mining**

The world has abundant coal resources which can be found on every continent, though quality varies between regions. The largest known coal reserves are located in the United States, Russia, China, Australia and India.

The widespread availability of coal resources means that it is subjected to much less political instability than petroleum.

According to the World Energy Council (2013) world coal reserves are estimated at around 870 billion tonnes, which are sufficient to last 115 years at current production rates. This is considerably longer than conventional oil and gas reserves. Asia and southern Africa have large coal reserves; both regions have large portions of their populations with inadequate electricity access. As such, coal is likely to play an important role in meeting their growing energy needs.

## Coal mining methods

Coal can be mined using one of two methods, open cut (surface) mining and underground (deep) mining. The method adopted will be largely determined by the geology of the coal deposit. Open cut methods are typically employed when the coal seam is close to the surface. When the coal seam is further from the surface, underground methods are generally more efficient (World Coal Institute 2009). The majority of Australia's production is sourced from open cut mines.

### Open-cut mining

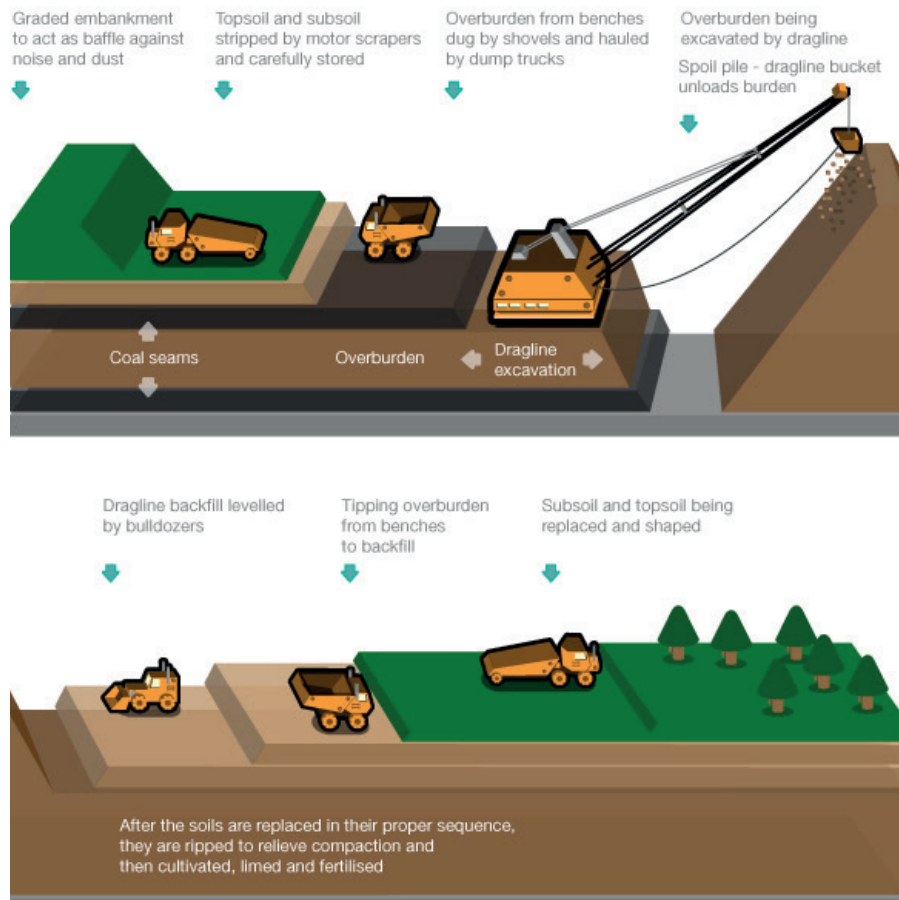
Open-cut operations are generally lower cost and recover more of the available coal than underground mining—around 90 per cent of the deposit can be recovered. Large open-cut mines employ large pieces of equipment including draglines, power shovels, trucks, bucket wheel excavators and conveyor belts. The surface area of an open-cut mine can cover several square kilometres (World Coal Institute 2009).

Before mining can commence the overburden, which is the layer of soil and rock between the coal seam and the surface, is broken up into small pieces using explosives (figure 34). It is then removed using either a dragline, power shovel and truck or bucket wheel depending on overburden depth. A **dragline** is the lowest cost overburden removal method but has a high capital cost. The dragline casts a large bucket long distances and collects the loose overburden by pulling the bucket back along the ground towards itself. The bucket is then emptied onto a pile. A **power shovel** removes the overburden using cables and a bucket. The shovel is generally on tracks and can rotate 360 degrees from a stationary position. The power shovel has more flexibility than the dragline and a lower capital cost, but its operating costs are higher. A **bucket wheel** is a continuous digging machine that uses a series of buckets to scoop up the overburden as the wheel rotates.

Once the coal seam has been exposed, it is drilled, fractured to loosen the coal and then systematically extracted in strips. The mined coal is then transported to either a coal preparation plant (discussed below) or directly to the power plant for use. When mining activities are completed, the land is rehabilitated (World Coal Institute 2009).



**Figure 34. Open-cut coal mining**



Source: World Coal Association 2015b.

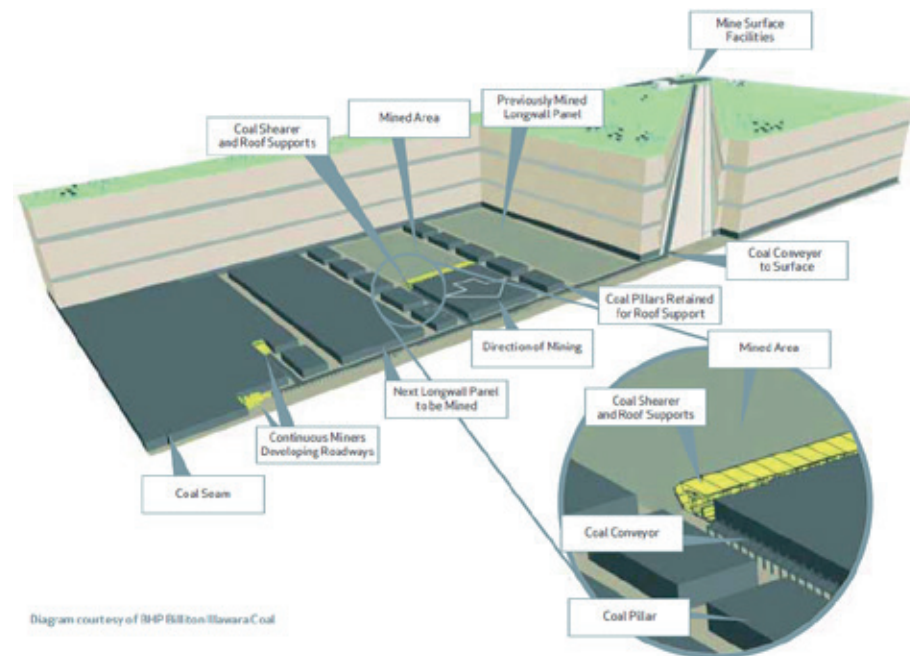
## Underground mining

There are two methods of underground mining for coal: bord and pillar and longwall mining. In bord and pillar mines, a grid of 'rooms' or 'bords' are cut into the coal seam, leaving behind 'pillars' to support the roof of the mine. The pillars left behind can represent up to 40 per cent of the coal contained in the seam. As such, this method is not very competitive and is becoming less common. However, the pillars can sometimes be extracted through 'retreat' mining where the pillars are mined as the workers retreat. The roof is left to collapse, which can cause subsidence, and the mine abandoned. Bord and pillar mining can begin faster than longwall mining and the technology employed is lower cost (World Coal Institute 2009).

Longwall mining extracts all the coal from a section of the coal seam, known as the 'face', using a mechanical shearer (figure 35). The face can range in length from 100 to 350 metres. The roof is temporarily held in place while the coal is being extracted by a self-advancing hydraulic-powered support. The self-advancing support protects workers from subsidence of the roof and is a safer underground method than bord and pillar. Once the coal has been extracted, the coal is transported to the surface by conveyor belt and the roof

is allowed to collapse. Up to 75 per cent of the coal in the deposit can be extracted through the panels of coal.

**Figure 35. Longwall mining**



Source: World Coal Institute 2009.

## Coal preparation

When coal is extracted from the mine, known as 'Run of Mine' (ROM), it often contains unwanted impurities like rocks and dirt. The treatment of coal is important in ensuring a consistent quality and specification; the type of treatment depends on the properties of coal and its intended use. The removal of waste products also reduces transportation costs, which are charged on a weight basis.

Coal preparation, also referred to as washing or beneficiation, involves crushing the ROM coal into smaller pieces. The larger pieces are treated in a process called 'dense medium separation', where coal is separated from the unwanted impurities through floatation. The coal is floated in a tank full of liquid of a particular density, usually a magnetite mixture. Because coal is lighter it floats to the surface and can be separated. The heavier materials sink to the bottom of the tank and are removed as waste. Smaller pieces are treated in many different ways. A centrifuge can be used to separate the coal based on differences in mass. The ROM coal is placed into a container in the centrifuge that spins very quickly, which causes the solids and liquids to separate. Froth flotation separates the coal based on different surface properties. Froth is created by blowing air into a mixture of water and chemicals. The bubbles created attract the coal, but not the waste, and are

skimmed off the top of the mixture to recover the fine particles of coal (World Coal Institute 2009).

## Part B—Coal-fired electricity generation

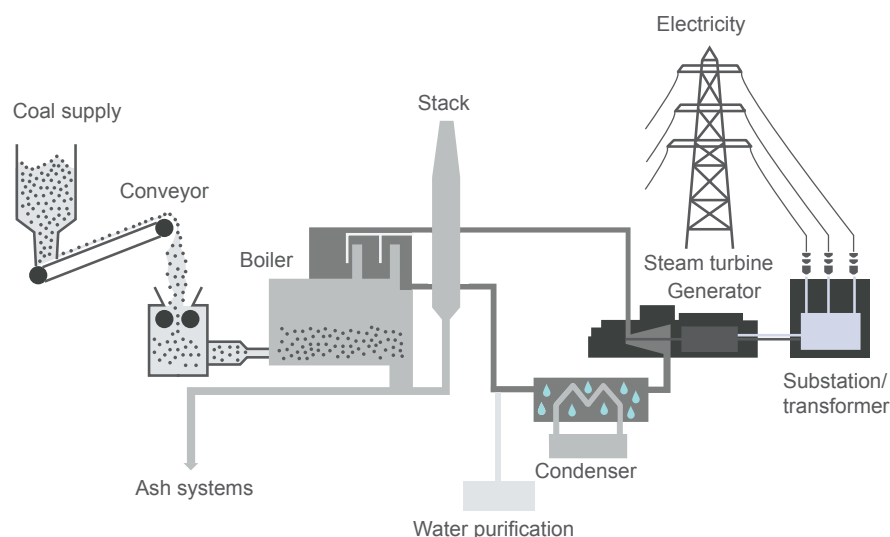
Coal-fired power is the key input to world electricity generation, accounting for around 40 per cent, or 9150 terawatt hours, of total generation. The technology is attractive because it is reliable, provides secure supply, has relatively low fuel costs and competitive capital and operating costs (Cziesla et al. 2009). However, coal-fired generation also presents challenges in terms of air pollution and CO<sub>2</sub> emissions (Beer 2009).

### How coal-fired generation plants work

Pulverised Coal Combustion (PCC) is the most common coal-based electricity generation technology. These plants use thermal coal that has been pulverised into a fine powder as this increases its surface area and makes it easier to burn. The powdered coal is blown into the combustion chamber of a boiler, where it is burnt at high temperatures. The heat and hot gases produced through the combustion of the coal converts water contained in tubes lining the boiler into steam (figure 36).

The steam is passed at pressure into a turbine that houses thousands of propeller blades. The steam pushes these blades, forcing the turbine to rotate at a high speed. The turbine is connected to an electrical generator that houses wire coils that rotate around a strong magnet to create electricity. Once it has passed through the turbine, the steam is condensed (converted back into water) and reinjected into the boiler to be reheated. The electrical output is transformed into higher voltages that can economically and efficiently be transported long distances (World Coal Institute 2009).

**Figure 36. Coal-fired power plant schematic**



Source: World Coal Association 2015c.

The amount of energy produced by the power plant for a given heat input is known as its thermal efficiency. By definition, thermal efficiency must range between 0–100 per cent. However, inefficiencies in the process such as friction and heat loss results in thermal efficiency being below 100 per cent. The thermal efficiency of a coal-fired power plant depends on the temperature and pressure of the steam generated in the boiler from the combustion of coal.

Most power plants are configured to run on a particular specification of coal. This influences the design of the boiler system, boiler size, types of pollution control and other auxiliary components. Plants designed to use low-energy coals require a larger boiler to enable combustion. If a plant uses coal of a lower quality than it was designed for, the operation and performance of the plant, and hence efficiency, is reduced (Miller 2013). When a coal of the required specification is not available, plant operators can blend two or more coals to replicate the specifications. However, it is difficult to predict the properties of these blends and could reduce the plants thermal efficiency or reduce plant availability as more frequent maintenance is required (IEA 2014b).

The different technologies used for coal-fired power generation have markedly different efficiencies, costs, and pollution outcomes (table 4).

**Table 4. Effect of plant efficiency on carbon emissions**

Efficiency (%)	26	30	35	40	45	50
CO <sub>2</sub> (g/kWh)	1252	1112	960	837	740	670

Source: IEA Clean Coal Centre 2014.

**Subcritical technologies** are the most common coal-fired plant globally, employing lower temperatures and pressures than other technologies. While they are generally cheaper and quicker to build than other technologies, they have lower efficiencies, typically around 30 per cent, and in some cases below. The drawbacks of subcritical technologies have led the IEA and other international bodies to argue that the global deployment and use of such technologies should be increasingly restricted, in favour of more efficient technologies. However, the World Bank's decision to cease funding for coal-fired projects in developing countries, unless there is no feasible alternative, is likely to stall the uptake of more efficient technologies that have higher capital costs unless other sources of finance can be organised.

**Supercritical** technologies use higher pressures and temperatures in the boiler than subcritical, achieving thermal efficiencies around 40 per cent, but have higher capital costs due to the need to use materials with higher heat and pressure tolerances. Supercritical plants are more economic with larger boilers and turbines. As such, a typical supercritical unit has a capacity of more than 500 megawatts. A supercritical plant emits around 6 per cent less CO<sub>2</sub> than a subcritical plant. Supercritical plants are designed to use coals with high energy content. If coal with lower energy content is used in the boiler, the plant can have severe losses in efficiency.

**Ultra-supercritical (USC)** plants operate at even higher temperatures and pressures than other plants, achieving efficiencies around 45 per cent. USC plants are built using advanced materials, require higher quality, low ash coals, and have higher capital costs (up to 40–50 per cent more than a subcritical plant) and longer build times. However, operating costs are typically lower because of reduced coal consumption. The overall power costs of USC is greater relative to other coal-fired technologies, unless coal prices are high, or a carbon price exists.

However, the benefits of using USC plants are evident when comparing a USC plant operating at 48 per cent efficiency to a subcritical plant operating at 32 per cent efficiency. The USC plant produces 50 per cent more power than the subcritical plant from the same coal input and reduces CO<sub>2</sub> emissions by more than a third. The poorest quality subcritical power plants can emit more than 1 tonne of CO<sub>2</sub> per megawatt hour, compared with 700 kilograms for USC plants (IEA Clean Coal Centre 2014).

**Advanced ultra-supercritical (AUSC)** plants are an extension on USC plants. However, the use of greater temperature and pressure puts a lot

more strain on plant components and the boiler can deteriorate over a prolonged period of time. Consequently, AUSC plants use steels that are heat-resistant, have a high melting-point and very high nickel content and are more expensive to build than USC. AUSC demonstration plants are being developed in China, Europe, India, Japan and the United States and are expected to achieve efficiencies approaching 50 per cent. The CO<sub>2</sub> emissions from an AUSC plant are expected to be up to 20 per cent lower than supercritical technology (IEA Clean Coal Centre 2014).

**Table 5. Typical pressure and temperature ranges, by technology type**

	Steam pressure, Mpa	Steam temperature, °C	Efficiency*, %
Subcritical	<22.1	Up to 565	33–39
Supercritical	22.1–25	540–580	38–42
Ultra-supercritical	>25	>580	>42

Source: IEA Clean Coal Centre 2014.

Note: \* Net efficiency calculated based on higher heating value of an inland plant using bituminous coal.

Although PCC is the most prominent technology, other technologies are being developed.

**Integrated Gasification Combined Cycle (IGCC)** plants gasify coal to produce a synthetic gas fuel and steam. The heated synthetic gas is then processed to remove sulphur, mercury and other particulates. The cleaned synthetic gas is then fed into a combustion turbine to generate electricity. The heat from the combustion exhaust gases is recovered to generate additional steam. The recovered steam, along with the steam produced during coal gasification is fed into a steam turbine to generate additional electricity. IGCC plants can achieve efficiencies of around 45 per cent and has low emissions because the fuel is cleaned before it is fired in the gas cycle turbine. However, they have higher capital and operating costs than PCC (IEA Clean Coal Centre 2014).

## Addressing the CO<sub>2</sub> challenge

Given the commonly projected increased demand for coal, particularly in emerging economies, there has been greater attention on reducing emissions from coal technologies to assist in meeting climate objectives. While coal-fired electricity generation is currently a large contributor to global CO<sub>2</sub> emissions, the technology is evolving. Newer coal-fired technologies operate at a higher efficiency, which means that they consume less coal per kilowatt hour generated, thereby improving environmental performance (figure 37). These technologies are often referred to as High-Efficiency, Low-Emissions (HELE) coal-fired power generation. Increasing the efficiency of a coal-fired power plant by 1 per cent can reduce its emissions by 2–3 per cent (IEA 2014b). As such, if the average efficiency of the global coal-fired power fleet was increased from its current average of 33 per cent to 40 per cent,

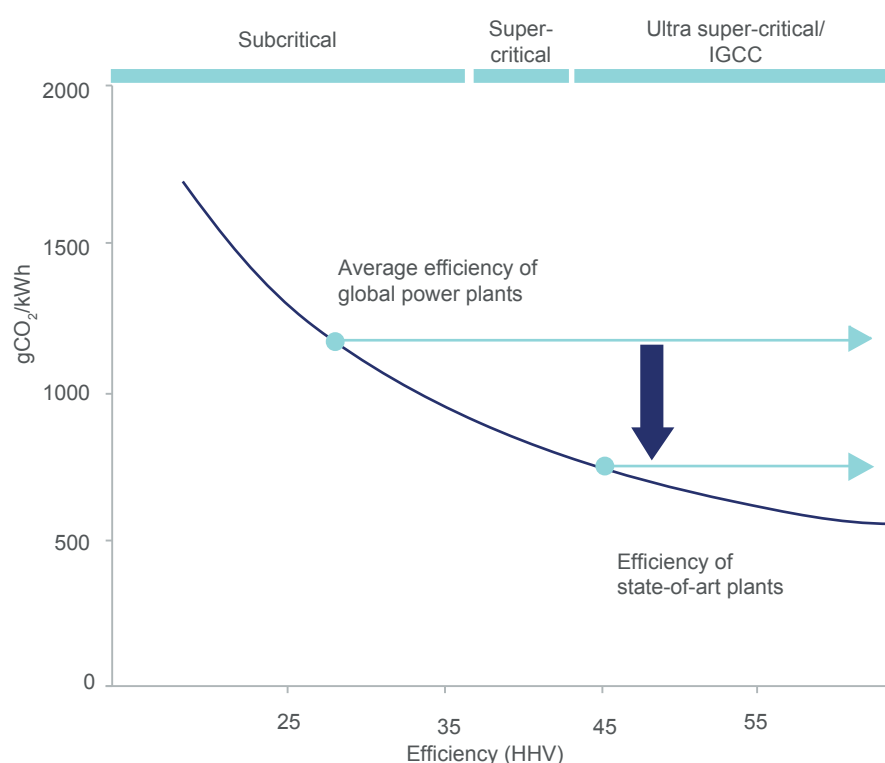


this could result in a 2 gigatonne reduction in global CO<sub>2</sub> emissions. This is equivalent to India's annual CO<sub>2</sub> emissions (IEA 2010).

Improving efficiency at existing power plants and ensuring that new coal-fired builds are based on newer technologies are cost-effective and readily available options for achieving a reduction in CO<sub>2</sub> emissions (Beer 2009). The efficiency of the global coal-fired electricity generation fleet is already improving. Around 64 per cent of the new coal-fired plants being developed world-wide are based on supercritical or ultra-supercritical technologies, up from 50 per cent in 2012. In addition, China, the world's largest coal consumer, is retiring its inefficient plants with close to 100 gigawatts of capacity decommissioned since 2006. India accounts for 60 per cent of the subcritical plants under development (IEA 2014b).

The 600 megawatt Isogo Power Station Unit 2 in Japan has the world's most advanced environmental control system that minimises sulphur dioxide and nitrogen dioxide emissions. The plant has an operating efficiency of 45 per cent and equating to a CO<sub>2</sub> reduction of over 25 per cent, compared with a plant operating at the global average (IEA 2014b).

**Figure 37. Relationship between CO<sub>2</sub> emissions and plant efficiency**



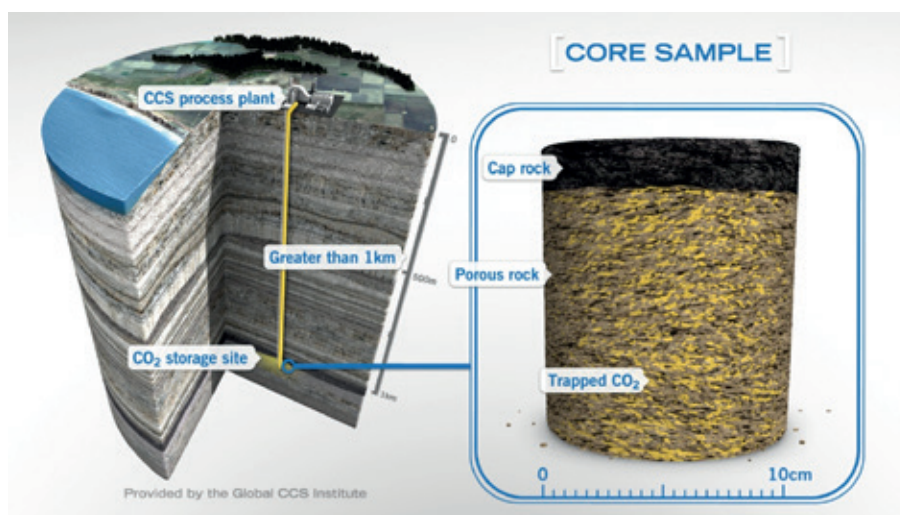
Source: IEA 2006.

## Carbon capture and storage

Carbon capture and storage (CCS) could be a key technology in achieving emissions reductions. In the IEA's 450 Scenario, wind generation would need to increase twenty-fold in the absence of CCS, compared with ten-fold with the adoption of CCS. Although the technology has been demonstrated, the pace of deployment will need to be accelerated to achieve climate goals (IEA 2014a, 2014b).

CCS prevents large amounts of CO<sub>2</sub> from being released into the atmosphere. The process involves capturing CO<sub>2</sub> from power plants or other industrial processes, compressing it for transportation, and injecting it deep into suitable rock formations, typically at depths greater than one kilometre. The CO<sub>2</sub> is captured by separating the CO<sub>2</sub> from the flue gas using chemical solvents, membranes or changing the operation of the boiler so that the coal is combusted in pure oxygen instead of air. The captured CO<sub>2</sub> is typically transported to a storage site via pipeline. The CO<sub>2</sub> is then injected via deep wells into a porous reservoir rock, such as sandstone, where it flows through the rock. To ensure the CO<sub>2</sub> remains trapped, geological storage sites are carefully selected so that there is a thick impermeable cap rock, such as mudstone, above the reservoir rock. This forms a seal and ensures the CO<sub>2</sub> remains trapped and cannot escape into the atmosphere. Storage sites are monitored to ensure the CO<sub>2</sub> remains trapped in the reservoir and there is no significant impact on groundwater resources, soil or air.

**Figure 38. Geological storage of carbon dioxide**



Source: GCCSI 2015a.

The identification and development of storage sites can be time consuming and expensive. Further, the installation of CCS technology has been estimated to increase the cost of a coal-fired plant by 45–75 per cent. CCS technology also requires large volumes of heat to regenerate solvents and electricity to operate the pumps and compressors. The extra energy required

to capture the CO<sub>2</sub> can reduce plant efficiency by 15–20 per cent and may also increase water usage. Accordingly, CCS is best applied to efficient plants (IEA 2014a).

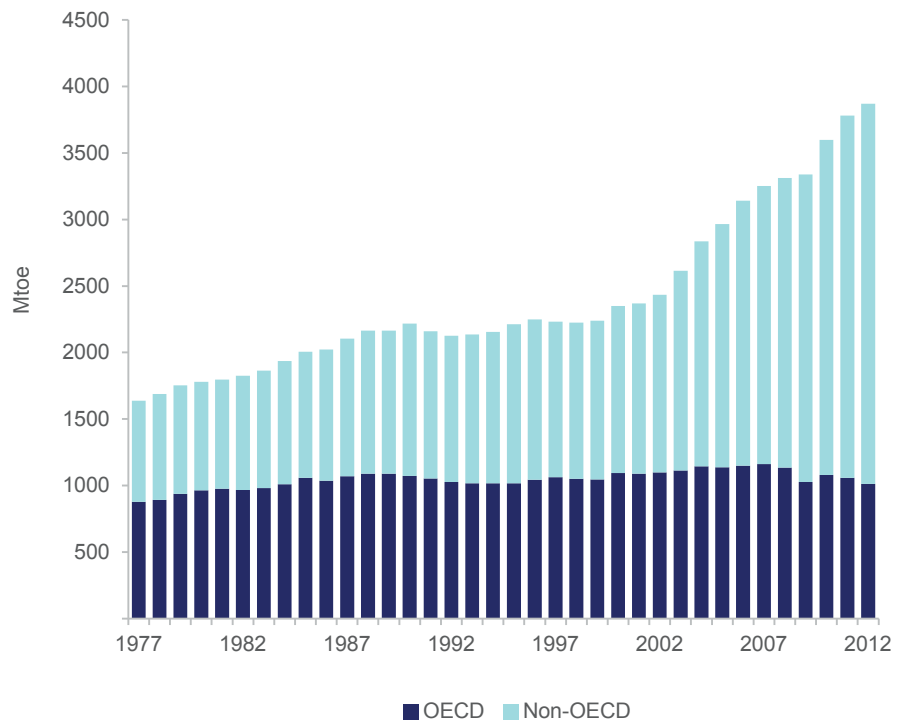
There are currently 13 operational large-scale CCS projects worldwide, storing around 27 million tonnes of CO<sub>2</sub> a year in total (GCCSI 2015b). Most of these projects capture CO<sub>2</sub> from natural gas processing plants and use the CO<sub>2</sub> for enhanced oil recovery. In October 2014, the world's first large-scale power sector CCS project—the Boundary Dam Integrated Carbon Capture and Sequestration Demonstration Project in Canada (CO<sub>2</sub> capture capacity of 1 million tonnes a year)—was commissioned. Another nine large-scale CCS projects are currently under construction.

## Part C—Trends in world coal use

Coal is an important component of the global energy mix because it is abundant, widely available and low cost. It is the main fuel used in electricity generation, accounting for 40 per cent of world electricity generation in 2012. Over the decade to 2013, world coal use increased by 50 per cent, almost approaching total world oil demand when measured in energy terms (Mtoe, million tonnes of oil equivalent). The majority of this growth was driven by non-OECD economies, particularly China. China's share of world coal consumption grew from around one third in 2003, to more than half by 2013.

While total coal consumption has been increasing, this has masked varied trends in coal-use between the OECD and non-OECD (figure 39). In 1990, global coal consumption was split roughly equally between the two regions (in contrast to oil and gas, where OECD still dominated). Since that time, OECD coal use has peaked and in some regions has begun to decline. For example, in the European Union, coal use peaked in the late 1980s, while US coal consumption (almost entirely in the power sector) peaked in 2005. Conversely, Chinese coal use quadrupled between 1990 and 2012, while Indian coal demand more than tripled. As a result, by 2012 OECD coal use was around a quarter of world coal use.

**Figure 39. World coal consumption, thermal and metallurgical**



Source: IEA 2014d.

Coal consumption can be usefully divided into metallurgical coal, used for steel production, and thermal coal, for energy production, mainly but by no means exclusively, in the power sector. Since 1990, metallurgical coal use has roughly doubled, led by non-OECD countries, which now account for 80 per cent of annual metallurgical coal use. Thermal coal use has more than doubled over this period, dominated by non-OECD use in the power and industrial sectors.

Coal use has traditionally been underpinned by production close to demand centres. Hence in 1990, less than 10 per cent of coal used globally was traded on seaborne markets, split roughly equally between metallurgical and thermal markets. Seaborne trade now accounts for around 17 per cent of world coal demand. However, seaborne thermal coal trade volumes have increased by more than five times, so that it now accounts for more than three quarters of global trade. While Japan has traditionally been the largest coal importer, and arguably the driving force behind the growth in seaborne coal trade, in 2009 China emerged as the largest importer, even though imports only account for around 6–8 per cent of its total coal use.

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