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India Energy Outlook

World Energy Outlook Special Report

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India is set for a period of rapid, sustained growth in energy demand: how could this re-shape the global energy scene?

This comprehensive analysis assesses the multiple challenges and opportunities facing India as it develops the resources and infrastructure to meet its energy needs. The report:

- Explores how major new policy initiatives, from "24x7 Power for All" to the "Make in India" campaign, affect India's energy outlook.
- Identifies the investment required in India's generation and grid in order to provide universal, secure and affordable electricity supply.
- Highlights the growing role of renewables, led by wind and solar, in India's energy future, alongside the continued importance of coal.
- Evaluates the energy security and environmental strains that accompany India's rise and how they can be addressed.
- Assesses the implications for a global energy system in which India exerts ever-larger influence.

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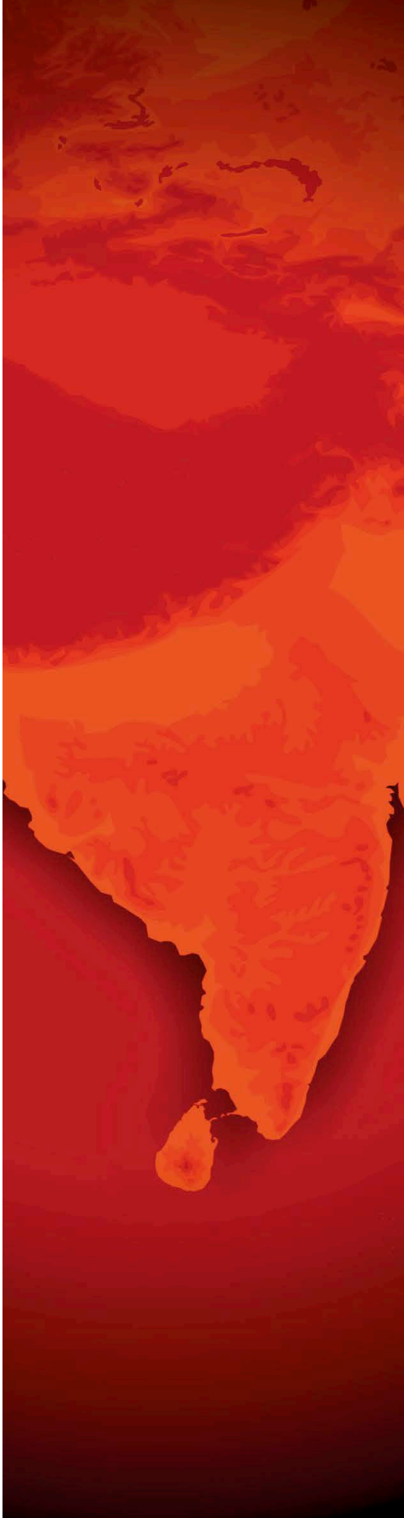

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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India is growing fast. Energy is central to achieving India's development ambitions, to support an expanding economy, to bring electricity to those who remain without it, to fuel the demand for greater mobility and to develop the infrastructure to meet the needs of what is soon expected to be the world's most populous country. What happens in India will increasingly influence the global energy economy. In this light, India, the subject of this *WEO-2015* special report, is a natural choice for an in-depth study.

Major responsibilities rest on the shoulders of the country's energy policy-makers; but they have major opportunities to chart a way forward for the energy sector that is distinctive: more secure, more sustainable, more innovative. As Mahatma Ghandi said, "You must be the change you wish to see in the world". India's climate pledge for the forthcoming climate summit in Paris (COP21) acknowledges this, stating an intention to follow "a cleaner path than the one followed hitherto by others at a corresponding level of economic development". To this end, India has established goals rapidly to expand its use of renewable energy and more efficient technologies.

The path ahead is not straightforward, nor is it for outsiders to dictate. In this report, we do not seek to prescribe but aim, instead, to provide data and objective analysis to inform India's own policy choices and to assess what they might mean for India's economic growth and its interactions with the wider energy world.

One unmistakeable conclusion is that India's ties with the international energy system are set to deepen, intensifying India's dependence and influence on international markets, through trade, investment, clean technology cooperation and other channels.

International partnerships will be required to deliver the reliable, sustainable, affordable energy system that India wants and needs. This brings me to India's relationship with the International Energy Agency. It is my firm conviction – confirmed by this report – that India is a critical partner for the IEA: building even stronger ties with India is a key part of my vision for the Agency. There are clear mutual benefits from engaging India as a full participant in our work on policy, clean energy technology, market analysis and energy security. Their full realisation will take time, but I see the potential for closer institutional engagement and I am committed to the process.

I am encouraged in this by the great support that we have enjoyed across all parts of the Government of India throughout this study, as well as from industry and leading Indian academic and research organisations

Dr. Fatih Birol
Executive Director
International Energy Agency

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India, home to 18% of the world's population, uses only 6% of the world's primary energy. India's energy consumption has almost doubled since 2000 and the potential for further rapid growth is enormous. India's economy, already the world's third-largest, is growing rapidly and policies are in place to press ahead with the country's modernisation and an expansion of its manufacturing. If a well-managed expansion of energy supply can be achieved, the prize in terms of improved welfare and quality of life for India's 1.3 billion people is huge – first and foremost for the estimated 240 million that remain today without access to electricity. Policy-makers at national and state levels are intensifying their efforts to ensure that energy is a spur, rather than a hindrance, to India's advancement, looking to removing obstacles to investment in energy supply while also focusing on energy efficiency and pricing reform (the deregulation of diesel prices in late 2014, taking advantage of the fall in the oil price, means that all oil-based transport fuels are now subsidy-free). Coal is by far the most important fuel in the energy mix, but India's recent climate pledge underlined the country's commitment to a growing role for low-carbon sources of energy, led by solar and wind power. With major reforms of India's system of energy provision planned or underway, the aim of this *World Energy Outlook* (WEO) Special Report is not to prescribe a path for India, but to provide a coherent framework in which India's policy choices can be assessed, considering their implications not only for the country's development, energy security and environment, but also for a global energy system in which India plays an ever-greater role.

India seizes the centre of the world energy stage

India is set to contribute more than any other country to the projected rise in global energy demand, around one-quarter of the total: even so, energy demand per capita in 2040 is still 40% below the world average. India's total energy demand more than doubles in our main scenario, propelled higher by an economy that is more than five times larger in 2040 and a demographic expansion that makes India the world's most populous country. With energy use declining in many developed countries and China entering a much less energy-intensive phase in its development, India emerges as a major driving force in global trends, with all modern fuels and technologies playing a part. Surging consumption of coal in power generation and industry makes India, by a distance, the largest source of growth in global coal use. Oil demand increases by more than in any other country, approaching 10 mb/d by 2040. India steps up its deployment of renewables, led by solar power, for which India becomes the world's second-largest market. Natural gas consumption also triples to 175 bcm (although, at 8% in 2040, it still plays a relatively limited role in the overall energy mix). Solid biomass, mainly fuelwood, is the only major source of energy that does not see a large increase. This mainstay of the rural energy economy is the primary cooking fuel for some 840 million people in India today; its use in traditional stoves is a major cause of indoor air pollution and premature death. Its gradual (albeit not complete) displacement by alternative fuels in our projections to 2040 is achieved thanks to rising incomes and supportive policies; these include one of the world's largest cash transfer programmes, which subsidises the purchase of LPG cylinders via payments to individual bank accounts, rather than via an intervention affecting end-user prices.

India's urbanisation is a key driver of energy trends: an additional 315 million people – almost the population of the United States today – are expected to live in India's cities by 2040. This transition has wide-ranging effects on energy use, accelerating the switch to modern fuels, the rise in appliance and vehicle ownership and pushing up demand for construction materials. Three-quarters of the projected increase in energy demand in residential buildings comes from urban areas, driving the sector's energy use away from solid biomass (two-thirds of the total today) and towards electricity and oil (45% and 15% of the 2040 total, respectively). Since most of the 2040 building stock has yet to be constructed, there is a tremendous opportunity for India to expand and tighten efficiency standards and ensure that future demand for energy services – notably for cooling – is met without putting undue strain on energy supply. Successful initiatives include a huge and cost-effective programme to replace old, inefficient light bulbs with LEDs, but the scope of other efficiency measures for buildings and appliances, while expanding, is still far from comprehensive. The "Smart Cities" programme, launched in 2015, puts a welcome emphasis on integrated planning and provision of urban services (including power, water, waste and mass transportation), although faces the considerable challenge of coordinated delivery across different branches and levels of government.

India's need for new infrastructure underlies strong demand for energy-intensive goods, while the rising level of vehicle ownership keeps transport demand on an even steeper upward curve. Energy use in industry is the largest among the end-use sectors, its share in final consumption rising above 50% by 2040. Industrial energy use is buoyed by substantial growth in output of steel, cement, bricks and other building materials, and by the expansion of domestic manufacturing encouraged by the "Make in India" initiative. An innovative efficiency certificate scheme helps to dampen demand growth in the energy-intensive industries; the task of raising awareness and financing efficiency improvements in other sectors (such as the brick industry, which consists of more than 100 000 small producers) is more difficult. In the transport sector, adding more than 250 million passenger cars, 185 million two- and three-wheelers and 30 million trucks and vans to the vehicle stock by 2040 explains two-thirds of the rise in India's oil demand, mitigated only in part by new fuel-efficiency standards. The policy challenges are to improve the nation's road infrastructure while also encouraging rail freight (via dedicated freight corridors) and providing effective mass transport (as with the metro rail systems in Delhi and other cities).

India's path to power

India's power system needs to almost quadruple in size by 2040 to catch up and keep pace with electricity demand that – boosted by rising incomes and new connections to the grid – increases at almost 5% per year. The power system has grown rapidly in recent years, but the poor financial health of many local distribution companies remains a key structural weakness: low average end-user tariffs, technical losses in the network, and high levels of non-payment for electricity mean that distribution company revenue often fails to cover the costs owed to generators. This has created a cycle of uncertainty for generators and held back much-needed investment in network infrastructure. The situation varies from state to state, but stimulating the necessary grid strengthening and capacity additions requires pressing ahead with regulatory and tariff reform and a robust system of permitting and approvals for new projects. In the meantime, regular load-shedding in many parts of the country obliges those consumers who can afford it to invest in costly back-up options, and results in poor quality of service for those who cannot. Taking population growth into account as well as the high policy priority to achieve universal electricity access, India adds nearly 600 million new electricity consumers over the period to 2040. The vast majority of Indians continue to receive their power via the grid, but mini-grid and off-grid solutions provide more than half of the electricity supply to those gaining access in our projections, especially in areas distant from existing transmission lines or of lower population density.

Over 50% of new generation capacity to 2040 comes from renewables and nuclear, while new coal-fired plants in India represent nearly half of the net coal capacity added worldwide. Keeping pace with the demand for electricity requires nearly 900 GW of new capacity, the addition of a power system four-fifths the size of that of the United States today. Uncertainty over the pace at which new large dams or nuclear plants can be built means strong reliance on solar and wind power (areas where India has high potential and equally high ambition) to deliver on the pledge to build up a 40% share of non-fossil fuel capacity in the power sector by 2030. Some 340 GW of new wind and solar projects, as well as manufacturing and installation capabilities, are galvanised to 2040 by strong policy support and declining costs, although the pace of deployment is slowed by anticipated issues with networks, land use and financing. Decentralised rooftop solar and off-grid projects account for around 90 GW of this total, but the bulk of the additions is utility-scale. Balancing a power system in which variable renewables meet one-fifth of power demand growth requires flexibility from other sources (a role largely filled by gas-fired plants in our projections) and a much more resilient grid. The share of coal in the power generation mix falls from three-quarters to less than 60%, but coal-fired power still meets half of the increase in power generation. A shift to more efficient technologies brings up average coal plant efficiency significantly. Other measures, including the announced moves to higher standards for vehicle emissions and fuel quality, help to limit the growth in energy-related emissions of particulates, fumes and other local pollutants. Nonetheless, without a continuous focus on emissions control technologies in the power sector, industry and transport, India faces the risk of a deterioration in urban air quality.

Domestic production strains to keep pace

A large expansion of coal output makes India the second-largest coal producer in the world, but rising demand also means that India becomes, before 2020, the world's largest coal importer, overtaking Japan, the European Union and China. Reforms to the system of coal procurement and contracting underpin new mining investment and a more efficient allocation of coal to consumers, including an expansion of competitively-priced imports in parts of coastal India. Growth in production is constrained by the concentrated structure of the coal industry, issues of land use and permitting, and infrastructure bottlenecks, but is sufficient to bring dependence on imports back down to current levels around 30%, from a peak of around 40% reached in 2020. Coal demand that is two-and-a-half-times higher than today by 2040 (although still only around half the projected level in China) is the main factor behind a large rise in India's energy-related CO_2 emissions. These nearly triple to reach 5 gigatonnes in 2040, a significant contribution to the rise in global emissions over this period. Nonetheless, relative to the size of the economy, energy-related CO_2 emissions fall in line with India's pledge to reduce its emissions intensity by 33-35% below 2005 levels by 2030, and, expressed on a per capita basis, emissions remain some 20% below the world average in 2040.

Production of oil and gas falls well behind the growth in demand: India's reliance on oil imports rises above 90% by 2040, requiring constant vigilance as to the implications for energy security. India has a relatively small but still under-explored hydrocarbon resource base, leaving potential upside to our projected 700 kb/d of oil output in 2040 and, in particular, to the 90 bcm of gas output, if licensing and pricing arrangements are right. India is the world's third-largest importer of crude oil, although a large and efficient refinery sector gives it a surplus of oil products, mainly transport fuels, for export. In our projections, crude imports rise to 7.2 mb/d in 2040 (second only to China), sourced predominantly from the Middle East. India's refinery capacity is projected to rise steadily and refinery output is increasingly directed to meet rising domestic demand. Indian refiners face an ever-more competitive product export market, particularly with the envisaged expansion of refining capacity in the Middle East.

"Make in India" needs energy to work and needs efficiency to prosper

Putting manufacturing at the heart of India's growth model means a large rise in the energy needed to fuel India's development. Industry-led growth requires at least 10-times more energy per unit of value added compared with growth led by the services sector. In an Indian Vision Case, we examine the implications of accelerated realisation of key Indian policy targets, including the "Make in India" campaign to promote manufacturing and the "24x7 Power for All" drive for universal, round-the-clock electricity supply. Fully reliable provision of power and new employment opportunities in the manufacturing sector give extra impetus to India's economic and social development and its transition to an urban society. The additional demands on the energy system come primarily from industry, not only from energy-intensive sectors, but also from other industries that are targeted by the "Make in India" campaign such as textiles, food processing, machinery and industrial equipment. Energy use for road freight, residential consumption and for a more mechanised and productive agricultural sector also rise. To avoid that this extra demand exacerbates energy security and environmental strains requires an even-stronger commitment to energy efficiency as a central pillar of India's energy strategy, alongside an unwavering push for low-carbon energy and high standards of pollution control.

Meeting India's energy needs requires a huge commitment of capital

India requires a cumulative $2.8 trillion in investment in energy supply in our main scenario, three-quarters of which goes to the power sector, and a further $0.8 trillion to improve energy efficiency. Investment in energy supply is held at similar levels in the Indian Vision Case, but only because of a near-doubling in spending on greater efficiency. Mobilising cost-efficient investment at average levels of well above $100 billion per year is a constant challenge for Indian policy at national and state levels, requiring effective coordination between multiple institutions and levels of government (the model of "co-operative federalism"), continued efforts to overhaul India's energy regulatory framework and to simplify an often-complex business environment. A transparent system of approvals and clearances needs to allow viable projects to move ahead according to a predictable timetable, while safeguarding the consultation and accountability that is essential to win public consent. India will also need to call upon a broader range of investors and sources of finance than has been the case in the past, not least in order to relieve the scarcity of long-term finance on suitable terms for low-carbon investment. Sustainable and affordable energy, underpinned by energy technology cooperation and innovation, is indispensable to India's outlook for economic growth and poverty reduction; the carbon intensity of India's development is also a critical barometer of the success or failure of efforts to tackle global climate change. There is a clear mutual interest, shared by India and the international community, in strong support for India's drive to deploy more efficient and low-carbon technologies.

Every year the International Energy Agency's (IEA) *World Energy Outlook (WEO)* examines in depth the prospects of a country or region of particular significance to the global energy outlook. This year the spotlight falls on India, as it is increasingly evident that it will command a central position in global energy affairs. As the country grows, so too do the opportunities and challenges linked to its development, with implications not only for its own energy security and the environment, but also for the greater global energy system.

This special report utilises the same overall policy and modelling assumptions that underpin the *World Energy Outlook 2015 (WEO-2015)*. A detailed description of these can be found in Chapter 1, Introduction and scope, of the *WEO-2015* as well as for reference on the website: *www.worldenergyoutlook.org/weo2015/*. This includes all of the overarching assumptions used for the global modelling effort that underpins this report, as well as the energy price trajectories.

The report is structured as follows:

- Chapter 1 sets the scene by analysing India's energy sector as it is today, outlining the opportunities and challenges that accompany its rapid economic and energy demand growth. It details the existing energy architecture, including the power sector and other energy-consuming sectors, the scale of India's energy resources and its energy production trends. It also highlights the important economic, policy and social factors that shape India's energy development and investment decisions, including energy prices and affordability, land use, and environmental factors such as local air pollution, CO_2 emissions and water availability. In addition, it explains the analytical approach for the projections that follow.
- Chapter 2 provides a detailed outlook for energy demand in India to 2040, including an in-depth look at the end-use sectors and the power sector and assesses the impact that energy use will have on local air pollution. It also examines the impact of a period of sustained lower oil prices on India's energy system and economy.
- Chapter 3 focuses on India's energy resources, covering the spectrum of fossil fuels, renewables and nuclear. It assesses the scale of these resources against the increase in energy demand, what will be required to enable future exploitation of its domestic resources and the outlook for international trade.
- Chapter 4 draws out some of the wider implications of the prospective energy transition in India. First, on the basis of the projections of the New Policies Scenario and then, on the basis of an Indian Vision Case, which examines how the country's energy system would evolve if key targets, such as the "Make in India" campaign and universal round-the-clock electricity supply, are achieved in full. Furthermore, it analyses the level of investment required, in addition to the regulatory framework and other measures necessary, to help secure the investment to ensure energy supply and improve energy efficiency.

Energy in India today

Setting the scene

Highlights

- India is in the early stages of a major transformation, bringing new opportunities to its 1.3 billion people and moving the country to centre stage in many areas of international affairs. The energy sector is expanding quickly but is set to face further challenges as India's modernisation and its economic growth gather pace, particularly given the policy priority to develop India's manufacturing base.
- Energy use has almost doubled since 2000, and economic growth and targeted policy interventions have lifted millions out of extreme poverty; but energy consumption per capita is still only around one-third of the global average and some 240 million people have no access to electricity. In these circumstances, even with a growing focus on energy efficiency and subsidy reform, there are strong underlying reasons to expect continued rapid growth in energy demand.
- Three-quarters of Indian energy demand is met by fossil fuels, a share that has been rising as households gradually move away from the traditional use of solid biomass for cooking. Coal remains the backbone of the Indian power sector, accounting for over 70% of generation and is the most plentiful domestic fossil-fuel resource, although, as in the case of oil and gas, dependence on coal imports has grown in recent years. India was the world's third-largest importer of crude oil in 2014, but is also a major exporter of oil products, thanks to a large refining sector.
- Power generation capacity has surged over recent years, but the outlook for the sector is clouded by the precarious financial situation of local distribution companies and large losses in the transmission and distribution networks. India has 45 GW of hydropower and 23 GW of wind power capacity, but has barely tapped its huge potential for renewable energy. India is, however, aiming high in this area, with a target to reach 175 GW of installed renewables capacity by 2022 (excluding large hydropower), which is a steep increase from today's level of 37 GW. Solar power is a key element of the government's expansion plans.
- India's federal constitutional system distributes powers for energy between the central and state-level governments. Indian policy-makers are making strenuous efforts to remove obstacles to investment in energy supply, while moving ahead with complementary policies on efficiency and energy pricing that can constrain growth in consumption; several national ministries and other state bodies oversee different aspects of energy, complicating the task of formulating and implementing a unified strategy. Policy and investment decisions are much influenced by the sensitivity of land and water use, end-user tariffs and affordability, as well as the worsening air quality in many of India's major cities.

Introducing the special focus on India[1]

India is in the midst of a profound transformation that is moving the country to centre stage in many areas of global interaction. A vibrant democracy that is home to over one-sixth of the world's population and its third-largest economy, India's modernisation has been gathering speed and new policies have been introduced to unleash further growth. The opportunities are huge, but so is the size of the remaining challenges: although incomes and corresponding standards of living are on the rise, India is still home to a third of the world's poor and gross domestic product (GDP) per capita is well below the international average.

India's energy sector has grown tremendously in recent years. Further economic and population growth, allied to structural trends such as urbanisation and the nature of the envisioned industrialisation, point unmistakeably to a trend of continued rapid expansion in demand for energy. Recognising this challenge, Indian policy-makers are making strenuous efforts to remove obstacles to investment in energy supply, while moving ahead with complementary policies on efficiency and energy pricing that can constrain growth in consumption. The analysis and findings in this special focus on India disclose these multiple pressures and show how policies can affect the evolution of the Indian energy sector so as to realise the huge benefits that a well-managed expansion of energy provision will bring. No effort is made here to prescribe a path for India; our intention is, rather, to provide a coherent framework to contribute to the policy choices that India itself will make, drawing out the possible implications of these choices for India's development, energy security and environment, as well as for the global energy system.

Key energy trends in India[2]

Demand

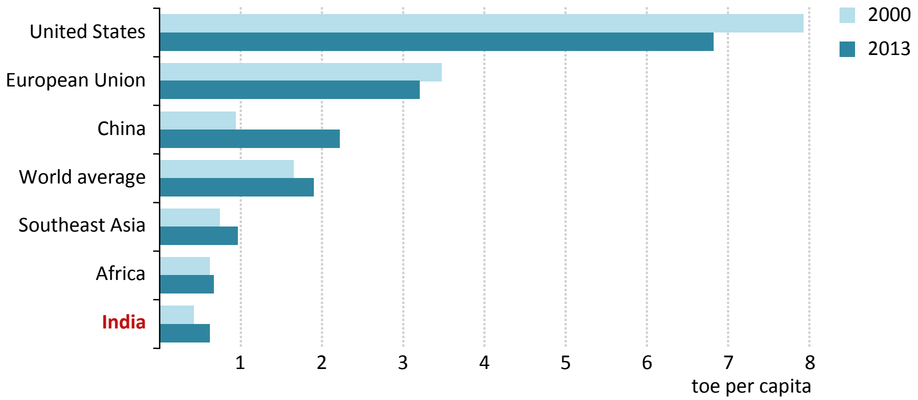
India has been responsible for almost 10% of the increase in global energy demand since 2000. Its energy demand in this period has almost doubled, pushing the country's share in global demand up to 5.7% in 2013 from 4.4% at the beginning of the century. While impressive, this proportion is still well below India's near 18% current share of global population, a strong indicator of the potential for further growth. Expressed on a per-capita basis, energy demand in India has grown by a more modest 46% since 2000 and remains only around one-third of the world average, slightly lower than the average for the African continent (Figure 1.1). One reason is that a significant part of the Indian

1. This analysis has benefited greatly from discussions with Indian officials, industry representatives and experts, notably during a high-level *WEO* workshop, organised in partnership with the National Institution for Transforming India (NITI Aayog) and held in New Delhi in April 2015.

2. The data used in this special focus are from IEA databases, which rely on a range of Indian official and other sources. As explained in Box 1.3 (see section on "Policy and institutional framework"), adjustments in some instances for IEA definitions and methodology mean that the data may differ slightly from those used elsewhere. The base year for this study is 2013, as it is the last year for which comprehensive historical data were available at the time of writing, though more recent data have been incorporated wherever possible.

population remains without modern and reliable energy: despite a rapid extension of the reach of the power system in recent years, around 240 million people in India lack access to electricity.

Figure 1.1 ▷ Per-capita energy consumption in India and selected regions



Note: toe = tonnes of oil equivalent.

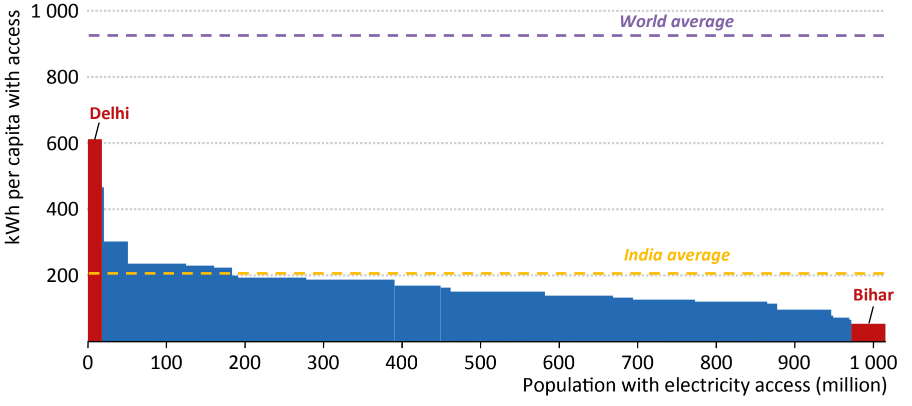
The widespread differences between regions and states within India necessitate looking beyond national figures to fully understand the country's energy dynamics. This is true of all countries, but it is particularly important in India, both because of its size and heterogeneity, in terms of demographics, income levels and resource endowments, and also because of a federal structure that leaves many important responsibilities for energy with individual states. For example, figures for residential electricity consumption per capita (for those with access to electricity) show a broad range between the area with the highest levels, in Delhi – the only part of India with consumption higher than the non-OECD average – and other states (Figure 1.2). Residential electricity consumption (for those with access) remains far below the world average and is ten-times lower than OECD levels. Average residential consumption in Bihar, at around 50 kilowatt-hours (kWh) per capita per year, is consistent with an average household use of a fan, a mobile telephone and two compact fluorescent light bulbs for less than five hours per day.

Energy demand has almost doubled since 2000, but this is slower than the rate of economic growth over the same period (Figure 1.3). This is due in part to the shift away from bioenergy[3] consumption in the residential sector, the rising importance of the services sector in the Indian economy and increased policy efforts directed at end-use energy efficiency. As a result, it took 12% less energy to create a unit of Indian GDP (calculated on the basis of purchasing power parity [PPP]) in 2013 than was required in 1990. The amount of energy required to generate a unit of GDP (PPP basis) in India is slightly lower than the global average. Even so, much energy is lost or used inefficiently, notably in the power

3. Bioenergy includes solid biomass, biofuels and biogas.

sector because of the generation technologies used, the poor state of the transmission and distribution infrastructure and the relatively low efficiency of end-use equipment. Significant untapped energy efficiency potential remains across the entire energy system, which could help temper the further growth in energy consumption.

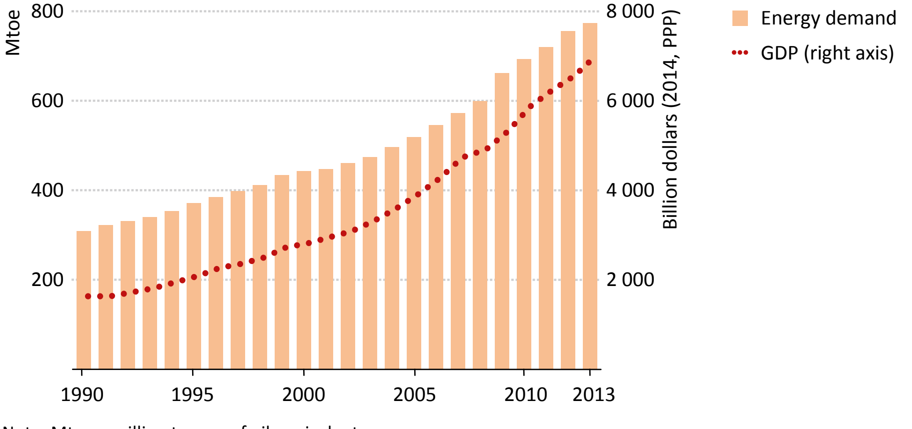
Figure 1.2 ▷ Annual residential electricity consumption per capita by state in India (for those with access), 2013



Note: Annual residential electricity consumption per capita (for those with access) by state is estimated by dividing the annual residential electricity consumption by the number of people with electricity access for each state. This estimate is not comparable with the common "electricity consumption per capita" indicator, which takes into account electricity consumption of all sectors divided by total population.

Sources: National Sample Survey Office, (2014a); Central Electricity Authority, (2014a); IEA analysis.

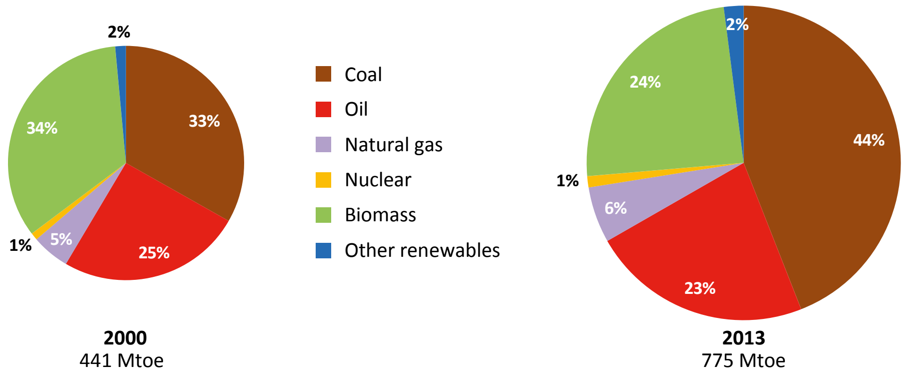
Figure 1.3 ▷ Primary energy demand and GDP in India



Note: Mtoe = million tonnes of oil equivalent.

Almost three-quarters of Indian energy demand is met by fossil fuels, a share that has increased since 2000 because of a rapid rise in coal consumption and a decreasing role for bioenergy, as households move away from the traditional use of solid biomass for cooking (Figure 1.4). Coal now accounts for 44% of the primary energy mix (compared with under a third globally) – mainly because of the expansion of the coal-fired power generation fleet, although increased use of coking coal in India's steel industry has also played a part. The availability and affordability of coal relative to other fossil fuels has contributed to its rise, especially in the power sector. Demand for bioenergy (consisting overwhelmingly of solid biomass, i.e. fuelwood, straw, charcoal or dung) has grown in absolute terms, but its share in the primary energy mix has declined by almost ten percentage points since 2000, as households moved to other fuels for cooking, notably liquefied petroleum gas (LPG).

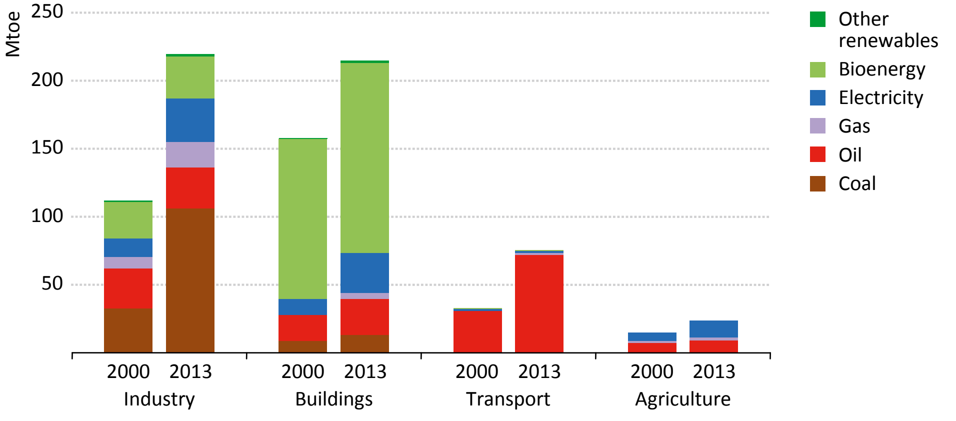
Figure 1.4 ▷ Primary energy demand in India by fuel



Oil consumption in 2014 stood at 3.8 million barrels per day (mb/d), 40% of which is used in the transportation sector. Demand for diesel has been particularly strong, now accounting for some 70% of road transport fuel use. This is due to the high share of road freight traffic, which tends to be diesel-powered, in the total transport use and also to government subsidies that kept the price of diesel relatively low (this diesel subsidy was removed at the end of 2014; gasoline prices were deregulated in 2010). LPG use has increased rapidly since 2000, reaching over 0.5 mb/d in 2013 (LPG is second only to diesel among the oil products, pushing gasoline down into an unusually low third place). The rise in LPG consumption also reflects growing urbanisation, as well as continued subsidies. Natural gas makes up a relatively small share of the energy mix (6% in 2013 compared with 21% globally). It is used mainly for power generation and as a feedstock and fuel for the production of fertilisers, although it also has a small, but growing role in the residential sector and as a transportation fuel. Hydropower, nuclear and modern renewables (solar, wind and geothermal) are used predominantly in the power sector but play a relatively small role in the total energy mix.

Energy demand had traditionally been dominated by the buildings sector (which includes residential and services) (Figure 1.5), although demand in industry has grown more rapidly since 2000, overtaking buildings as the main energy user in 2013. In the buildings sector, a key driver of consumption in both rural and urban areas has been rising levels of appliance ownership, especially of fans and televisions, and an increase in refrigerators and air conditioners in urban areas over the latter part of the 2000s. As a result, electricity demand in the buildings sector grew at an average rate of 8% per year over 2000-2013. The share of bioenergy in the buildings sector (mostly the traditional use of biomass for cooking and heating) has declined from 75% of the sector's total consumption in 2000 to two-thirds in 2013, as electricity and oil products have gained ground.

Figure 1.5 ▷ Energy demand by fuel in selected end-use sectors in India

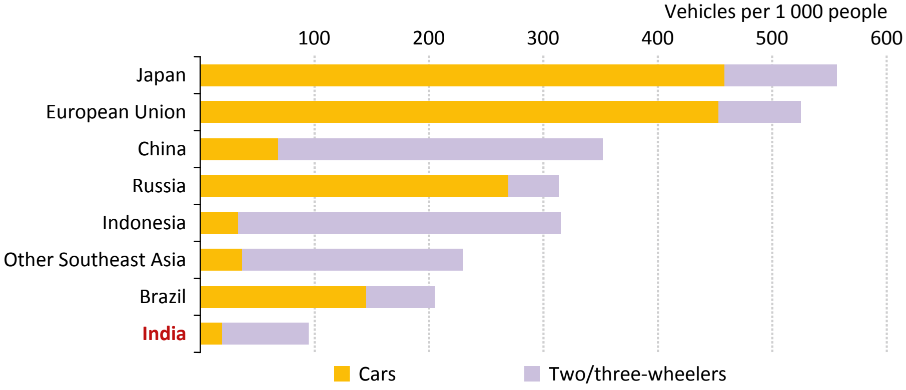


Notes: Other renewables includes solar photovoltaics (PV) and wind. Industry includes energy demand from blast furnaces, coke ovens and petrochemical feedstocks.

Industrial energy demand has almost doubled over the 2000-2013 period, with strong growth from coal and electricity. Large expansion in the energy-intensive sectors, including a tripling in steel production, is one component. Nonetheless, consumption levels of cement and steel are still relatively low for a country of India's size and income levels: consumption of cement is around 220 kilograms (kg) per capita, well behind the levels seen in other fast-growing economies and a long way behind the elevated levels seen in China in recent years (up to 1 770 kg per capita). The agricultural sector, though a small part of energy demand, is a key source of employment and since 2000 has accounted for roughly 15% of the increase in total final electricity demand as more farmers obtained electric pumps for irrigation purposes.

Over 90% of energy demand in the transport sector in India is from road transport. The country's passenger light-duty vehicle (PLDVs) stock has increased by an average of 19% per year since 2000, rising to an estimated 22.5 million in 2013, with an additional 95 million motorbikes and scooters (two/three-wheelers). Yet ownership levels per capita are still very low compared with other emerging economies and well below ownership levels of developed countries (Figure 1.6). Poor road infrastructure is a major constraint to broader vehicle ownership; according to the World Bank, one-third of the rural population lacks access to an all-weather road, making car ownership impractical – even in cases where it is affordable (World Bank, 2014).

Figure 1.6 ▷ Vehicle ownership in India and selected regions, 2013



Electricity

The provision of electricity is critical to India's energy and economic outlook and is a major area of uncertainty for the future. The country's electricity demand in 2013 was 897 terawatt-hours (TWh)[4], up from 376 TWh in 2000, having risen over this period at an average annual rate of 6.9%. Electricity now constitutes some 15% of final energy consumption, an increase of around four percentage points since 2000. As with all other demand sectors, further rapid growth is to be expected: around one-sixth of the world's population in India consumes about one-twentieth of global power output. With continued economic expansion, expanding access to electricity, urbanisation, an ever-larger stock of electrical appliances and a rising share of electricity in final consumption, pressures on the power system will persist and increase.

The situation varies from state to state (Box 1.1), but higher tariffs paid by commercial and industrial consumers are typically not enough to offset the losses arising from subsidies to residential and agricultural consumers, despite efforts to raise retail rates in recent years (see section on energy prices below). The consequent financial problems faced by local distribution companies are often exacerbated by shortfalls in subsidy compensation payments due from state governments and by poor metering and inefficient billing and collection, creating a spiral of poor performance, inadequate investment, high transmission and distribution losses and regular power outages. This is a key structural weakness for the energy sector as a whole.

On the supply side, India has some 290 gigawatts[5] (GW) of power generation capacity, of which coal (60%) makes up by far the largest share, followed by hydropower (15%)

4. Electricity demand is defined as total gross generation, including estimated off-grid generation, plus net trade (imports minus exports), minus own use by generators as well as transmission and distribution losses.

5. The figure is for total capacity as of end-2014 and includes grid-based and captive generation; it compares with capacity data for end-March 2015 from the Central Electricity Authority of 271 GW (utilities) and 47 GW (non-utilities); the bulk of the difference may be explained by additions in the first three months of 2015.

and natural gas (8%). The mix has become gradually more diverse: since 2000, almost 40% of the change in installed capacity was non-coal. This is reflected also in the figures for generation, which show how renewables are playing an increasingly important role (Figure 1.7). But, despite the increase in generation, India faces a structural shortage of power. For residential consumers, this constraint is most evident during periods of peak demand, typically in the early evenings as demand for lighting, cooling and other appliances surges (with the result that, where they can afford it, households often invest in small diesel generators or batteries and inverters[6] as back-up).

Box 1.1 ▹ Power fluctuations, from state to state

The provision of electricity is a shared responsibility between the central and state authorities in India: states have significant freedom to set electricity prices, the average subsidy level and the beneficiaries of the cross-subsidisation. In practice, there are large differences in circumstances between the various states and a wide range of performance across various indicators, such as progress towards universal access, success in reducing losses from theft, non-billing and non-payment, and electricity losses in transmission and distribution (for which six states registered total losses of less than 15% of available supply in 2012-2013, while four had losses greater than 40% [CEA, 2014a]). Steps to narrow or even to close the gap between end-user tariffs and the cost of supply also vary widely.

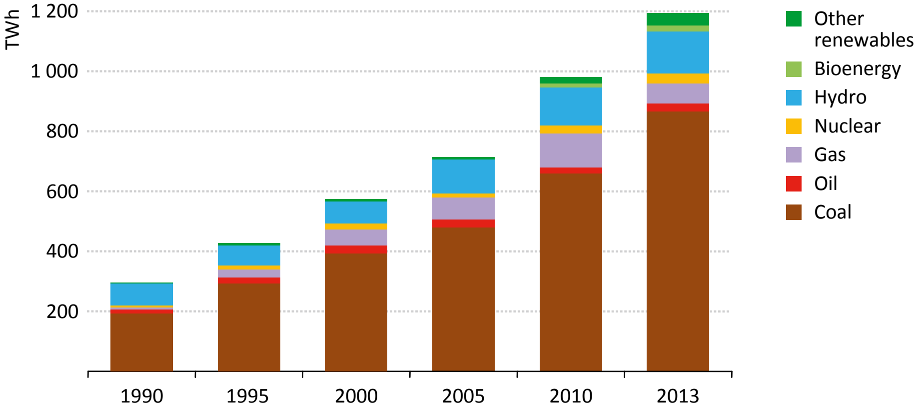
Part of the explanation is related to variations in income levels and population density, with low-income, densely-inhabited states tending to perform worse than average. States also differ in their resource endowments, both fossil fuel and renewables, as well as in their geographical proximity to coal mining areas and ports. All of these factors have a significant impact on how the local electricity sector is structured and performs. But policy formulation and efficacy of implementation are also important variables. Research by the World Bank has measured a series of outcome-based indicators for the different states against an index that assessed the actions taken by the respective governments, regulatory commissions and utilities to implement electricity sector reforms (in line with the objectives of the 2003 Electricity Act, a milestone in India's power regulation) (Pargal and Ghosh Banerjee, 2014).[7] Gujarat state was among the best in both policy formulation and implementation and overall there was a strong correlation between reforms and outcomes, with states either exhibiting a high commitment to reform alongside strong performance indicators, or the reverse.

6. Batteries and inverters of varying capacities charge from the grid when power is available and then discharge to power appliances during outages (typically charging during the day and then used as necessary during periods of peak demand in the evenings).

7. The index assessed progress in six areas, reflecting key objectives of the 2003 Electricity Act: the introduction of competition; enhanced accountability and transparency; cost recovery and commercial viability; access to electricity and rural electrification; improved quality of service and affordability of supply; and promotion of renewable energy.

Industrial consumers are also affected by unreliable and unpredictable power supply: around half of the industrial firms in India have experienced power cuts of more than five hours each week (FICCI, 2012). Elevated end-use industrial tariffs, allied to unreliable supply, lead many industrial and commercial consumers to produce their own electricity, using back-up diesel generators or larger plants (albeit not utility-scale). Energy-intensive industries, such as steel, cement, chemicals, sugar, fertilisers and textiles are key auto-producers, with cement producers, for example, estimated to produce around 60% of the electricity that they consume. This capacity has been growing steadily and is often coal-fired, relatively inefficient compared with utility-scale generation units and under-utilised (many companies need less electricity than their captive plants can produce, but there are obstacles to feeding this excess power into the grid). The increased use of captive generators, both at household and industrial levels, often worsens local air pollution.

Figure 1.7 ▷ Total electricity generation in India by fuel



Note: Other renewables includes solar PV and wind.

The solution to India's electricity dilemma is not only to raise average tariffs and add more capacity (although both will be essential over time), but also to deal with inefficiencies and bottlenecks. Although there is an overall shortage of power, utilisation rates in coal-fired plants have actually fallen considerably in recent years, down from a peak of almost 80% in 2007 to around 64% in 2014. The decline has been even more dramatic in the case of gas-fired power plants, which ran less than a fourth of the time on average in 2014 (CEA, 2014b). In some instances, particularly for gas plants supplying periods of peak demand, the financial situation of the distribution companies has meant that plants are not being called upon when needed. Another reason for low load factors lies with fuel supply problems, including shortages and quality issues in the case of coal (although the situation has improved in 2015, due to efforts to fast-track the approval of mines and increase oversight of production) and lower than anticipated domestic gas production, for which comparatively expensive liquefied natural gas (LNG) has not been a substitute in most cases (though the recent decline in the price of LNG has made imports more attractive).

The situation is not helped by the low efficiency generation technologies that prevail across much of India's existing fleet (meaning that more fuel is required to generate a unit of power). Over 85% of India's coal plants use subcritical generation technology, and the average efficiency of India's coal-fired fleet is just under 35%, below that of China or the United States. Poor coal quality (high ash content) and the relatively high ambient temperatures in India also play a role in lower efficiency levels. In some cases, generation has also run below capacity due to a lack of available transmission capacity. The creation of a national grid (the five regional grids were interconnected by end-2013) and continued progress in inter-state and inter-regional links has been and remains critical, given that resources and capacity for power generation are often not located close to the main centres of demand. Despite steps to encourage investment, including private investment, in transmission projects, expansion of the network has generally lagged behind that of generation; projects face numerous obstacles, notably over clearances. In 2011, the Central Electricity Authority (CEA) estimated that over 120 transmission projects were held up because the developer was unable to secure the necessary land and rights-of-way.

Access to modern energy

India has made great strides in improving access to modern energy in recent years. Since 2000, India has more than halved the number of people without access to electricity and doubled rural electrification rates. Nonetheless, around 240 million people, or 20% of the population, remain without access to electricity (Table 1.1).[8] The population without access is concentrated in a relatively small number of states: almost two-thirds are in two populous northern and north-eastern states, Uttar Pradesh and Bihar. In large swathes of India, including the majority of southern states, electrification rates are already well above 90%. Of the total without access, the large majority – some 220 million people – live in rural areas where extending access is a greater technical and economic challenge. In urban areas, electrification rates are much higher, but the quality of service remains very uneven, especially in India's large peri-urban[9] slum areas that are home to around 8.8 million households (National Sample Survey Office, 2014b).

India's rural electrification programme, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), was launched in 2005 and aimed to provide electricity to villages of 100 inhabitants or more and free electricity to people below the poverty line. The effective implementation of RGGVY has faced several challenges and there are strong variations in outcomes between states, as well as questions over the definition of access (Box 1.2).

8. This estimate for India's electrification rate is derived from the 68th National Sample Survey published in June 2014. However, this is a lower figure than that implied by the Census of India 2011, which gave a figure of 400 million without electricity (at that time). The 12th Five-Year Plan recognises the issue of discrepancies across different national data sources, stating that it may be due to differences in questionnaire design and needs to be examined further.

9. While the definition of peri-urban varies by country, United Nations Children's Fund defines it as an area between consolidated urban and rural regions (UNICEF, 2012).

In July 2015, RGGVY was subsumed within a new scheme, the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY). The main components of this scheme are the separation of distribution networks between agricultural and non-agricultural consumers to reduce load shedding, strengthening local transmission and distribution infrastructure, and metering. Among the issues that have held up progress with electrification is the need to find local solutions adapted to the specific circumstances of the remote settlements without access, and a variety of problems in securing authorisation for the necessary projects (e.g. land acquisition and rights-of-way for transmission lines and roads).

Table 1.1 ▷ Number and share of people without access to electricity by state in India, 2013

	Population without access (million)			Share of population without access		
	Rural	Urban	Total	Rural	Urban	Total
Uttar Pradesh	80	5	85	54%	10%	44%
Bihar	62	2	64	69%	19%	64%
West Bengal	17	2	19	30%	7%	22%
Assam	11	0	12	45%	9%	40%
Rajasthan	10	0	11	22%	2%	17%
Odisha	10	0	11	32%	4%	27%
Jharkhand	8	0	9	35%	4%	27%
Madhya Pradesh	7	1	8	16%	3%	12%
Maharashtra	6	1	6	11%	2%	7%
Gujarat	2	2	3	7%	6%	6%
Chattisgarh	2	0	3	14%	6%	12%
Karnataka	1	0	1	5%	1%	3%
Other states	3	2	6	2%	2%	2%
Total	**221**	**16**	**237**	**26%**	**4%**	**19%**

Source: National Sample Survey Office, (2014); Central Electricity Authority, (2014a); IEA analysis.

Aside from those without electricity, India also has the largest population in the world relying on the traditional use of solid biomass for cooking: an estimated 840 million people – more than the populations of the United States and the European Union combined. There is a host of issues associated with the traditional use of solid biomass for cooking, including the release of harmful indoor air pollutants that are a major cause of premature death, as well as environmental degradation as a result of deforestation and biodiversity loss. The government has made a major effort to address these issues, primarily through the subsidised availability of LPG as an alternative cooking fuel (see section below on energy prices).

Box 1.2 ▷ Defining access to electricity

Estimates of the number of people with or without access to electricity in different countries depend critically on how "access" itself is defined. These definitions can vary widely, resulting in disparities between various sources of data.[10] In the DDUGJY programme, a village is deemed electrified if basic infrastructure (transformer and distribution lines) has been provided, if public buildings have electricity or if at least 10% of the households have an electrical connection. However, there can be large discrepancies between village electrification and household electrification. Several states report high levels of village electrification, even though the connection rate at household level is much lower. In the state of Bihar, village electrification stands at 96%, while the household electrification rate is only 36%.

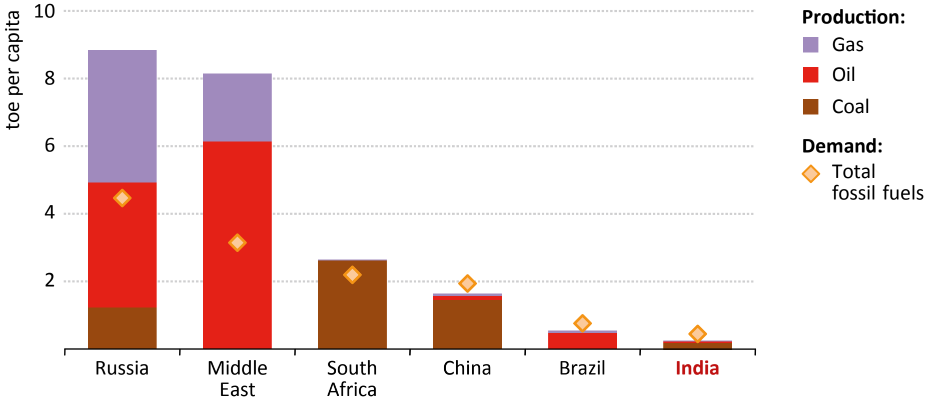
A recent National Sample Survey showed that higher reported rates of electrification were not producing the expected rise in actual power consumption (National Sample Survey Office, 2014a). In the state of Madhya Pradesh, for example, per-capita electricity consumption has been on a slightly declining trend, despite almost a 100% village electrification rate. Such findings raise the important question of the quality of service required to underpin access. According to DDUGJY, a minimum of 6-8 hours of electricity per day should be supplied to households. Most states meet this target, but some only just, as the infrastructure is inadequate and load shedding occurs as a matter of course. A recent survey conducted across six Indian states found that half of the households categorised in the lowest level of access actually had an electricity connection, and that, among the remainder of this category (those without any connection), two-thirds of the respondents had chosen not to adopt electricity for reasons of unaffordability or unreliability (Jain et al., 2015).

Energy production and trade

Fossil fuels supply around three-quarters of India's primary energy demand and, in the absence of a very strong policy push in favour of alternative fuels, this share will tend to increase over time as households move away from the traditional use of biomass. This high – and potentially growing – reliance on fossil fuels comes with two major drawbacks. India's domestic production of fossil fuels, considered on a per-capita basis, is by far the lowest among the major emerging economies (Figure 1.8), meaning that India has a structural dependence on imported supply. In addition, combustion of coal and oil products contributes to pressing air quality problems in many areas, as well as to global greenhouse gas (GHG) emissions.

10. The IEA definition of access to electricity is at the household level and includes a minimum level of electricity consumption, ranging from 250 kWh in rural areas to 500 kWh in urban settings per household per year. The electricity supplied must be affordable and reliable. The initial level of electricity consumption should increase over time, in line with economic development and income levels, reflecting the use of additional energy services.

Figure 1.8 ▷ **Fossil-fuel production and demand per capita by selected countries, 2013**



Coal

India has the third-largest hard coal reserves in the world (roughly 12% of the world total), as well as significant deposits of lignite. Yet the deposits are generally of low quality and India faces major obstacles to the development of its coal resources in a way that keeps pace with burgeoning domestic needs. In 2013, India produced almost 340 million tonnes of coal equivalent (Mtce), but it also imported some 140 Mtce – roughly 12% of world coal imports (61% from Indonesia, 21% from Australia, 13% from South Africa). With a view to limiting reliance on imports, the government announced plans in early 2015 to more than double the country's coal production by 2020.

The coal sector in India is dominated by big state-owned companies, of which Coal India Limited (CIL) is the largest, accounting for 80% of India's output. CIL has an unwieldy structure and is characterised by poor availability of modern equipment and infrastructure, an over-reliance on surface mining and very low productivity from a very large workforce. Around 7% of national production comes from captive mining, i.e. large coal-consuming companies that mine for their own use; private companies are not at present allowed to mine and market coal freely, though there are now some moves to open the coal market. At present, more than 90% of coal in India is produced by open cast mining. This method has relatively low production costs and is less dangerous than deep mining, but has a large, adverse environmental footprint in the form of land degradation, deforestation, erosion and acid water runoff.

Among the other problems facing the Indian coal sector is a mismatch between the location of hard coal reserves and mines, which are concentrated in eastern and central India, and the high-demand centres of the northwest, west and south. A tonne of coal must travel on average more than 500 kilometres (km) before it is converted to electricity, straining the country's rail network. There are also challenges related to the quality of the coal reserves. Most of the hard coal has low to medium calorific values and high ash content. The low heat value means that more coal must be burned per unit of electrical output, leading to higher local emissions. The ash content increases the cost of transporting coal, is corrosive and lowers the efficiency and load factor of coal-fired power plants. In addition, most power plants are designed for a specific coal quality; if not available, operators may choose to blend different coal types, which can adversely impact the performance of the power plant, as the properties of blends can vary widely.

The difficulty in expanding coal production in recent years has been related to a number of factors, including delays in obtaining environmental permits, land acquisition and rehabilitation and resettlement issues, infrastructure constraints (limited transport capacity to connect mines, dispatch centres and end-use destinations), insufficient coal-washing facilities to remove the ash and technological limitations (notably for underground mining). Other questions concerning future supply have arisen as a result of a Supreme Court decision in 2014 to annul the award of almost all of the coal blocks allocated since 2003 on the grounds that these awards had not been made on a transparent and competitive basis, although this has also opened an unexpected opportunity for the government to reform the coal sector in order to comply with the judgement. Two successful rounds of bidding have already been held to re-allocate some blocks and there is a possibility that private companies may be invited to participate in future rounds.

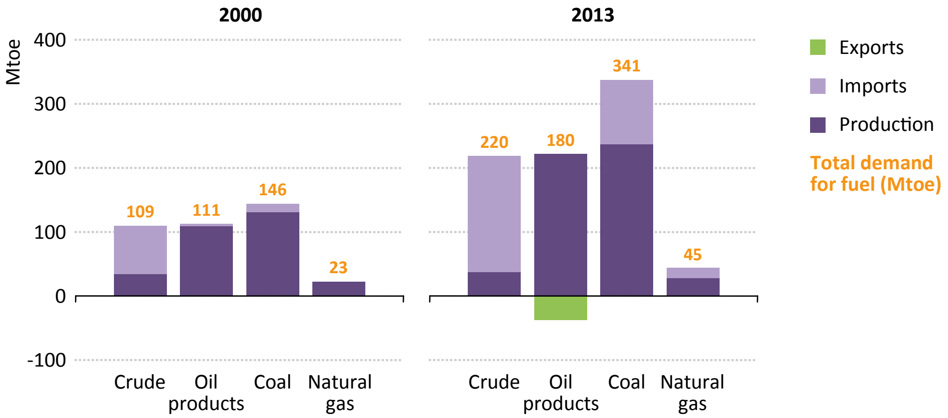
Oil and oil products

India is one of the few countries in the world (alongside the United States and Korea) that rely on imports of crude oil while also being significant net exporters of refined products (Figure 1.9). Domestic crude oil production of just over 900 thousand barrels per day (kb/d) is far from enough to satisfy the needs of 4.4 mb/d of refinery capacity. The output from the refinery sector, in turn, is more than enough to meet India's current consumption of oil products, at around 3.8 mb/d (with the exception of LPG, for which India imports about half of domestic consumption).

India has relatively modest oil resources and most of the proven reserves (around 5.7 billion barrels) are located in the western part of the country, notably in Rajasthan and in offshore areas near Gujarat and Maharashtra. The Assam-Arakan basin in the northeast is also an oil-producing basin and contains nearly a quarter of total reserves. Despite efforts to bolster oil production, including the opening of India's upstream sector to non-state investors, the sector has underperformed. Key impediments to investment include the complex regulatory environment (including uncertainty over contract terms and pricing arrangements), and a resource base that is still not well-explored and appraised. The upstream is still dominated by a few state-owned companies: about two-thirds of crude oil is produced by the Oil and Natural Gas Corporation Limited (ONGC) and Oil India Limited (OIL) under a pre-liberalisation nomination regime. Most of the remaining production comes from joint ventures with the national oil and gas companies and from blocks awarded under successive licensing rounds held under the New Exploration Licensing Policy introduced in 1999.

By contrast, the refining sector continues to strengthen. India has almost doubled its refining capacity in the last ten years and has added more than 2 mb/d of new capacity since 2005, with strong private sector participation from companies such as Reliance and Essar (India is now fourth in the world in terms of total refining capacity, behind only the United States, China and Russia). India's refinery assets include the largest refinery in the world, Reliance's Jamnagar complex, with over 1.2 mb/d of throughput capacity (more than India's domestic crude production). These capacity additions have given India a surplus of refined products, as the growth in oil product demand growth, even at an impressive 4.2% average annual rate, has been slower than the capacity boom.

Figure 1.9 ▷ Fossil-fuel balance in India



Note: Demand for crude oil shows refinery intake.

The refining capacity expansion, along with stagnant domestic crude oil output, means that India has become the third-largest crude oil importing country, behind the United States and China, with about 3.7 mb/d of import requirements (overall, India must import feedstock to meet 80% of its refinery needs for crude oil). The majority of ports that handle imported crude oil are located on the western side of India to accommodate oil tankers from the Middle East (the largest source of imports), Latin America and Africa. India has sought to diversify its sources of supply, especially as disruptions have plagued several of its suppliers such as Iran, Libya and Nigeria. The government announced in March 2015 a strategic aim to reduce reliance on imported crude by as much as 10% by 2022. The fall in the price of crude oil has also offered a cost-effective opportunity to build up emergency stockpiles of crude. With the expected completion of additional storage facilities for the strategic petroleum reserve expected in late 2015, India will have a combined storage capacity of about 37 million barrels, or roughly ten days worth of crude imports.

With refinery output exceeding total demand by roughly 1 mb/d, India is a net exporter of all refined products except LPG. India has been an important supplier of diesel to Europe and a regular supplier of transport fuel to Asia-Pacific and Middle Eastern countries. Its exports come mainly from the private sector refiners Reliance and Essar, while the public sector refiners supply the domestic market.[11] Growing product exports from India have contributed to refinery capacity rationalisation in both European and Asia-Pacific markets, as India's more modern, privately owned refineries, which are capable of efficiently processing Middle Eastern oil into high quality products, were able to gain market share from less complex refineries in Europe and Japan.

Natural gas

Natural gas has a relatively small share (6%) of the domestic energy mix. Optimism about the pace of expansion, fuelled by some large discoveries in the early 2000s, has been dashed by lower than expected output from offshore domestic fields. The main onshore producing fields are in the states of Assam in the northeast, Gujarat in the west and Tamil Nadu and Andhra Pradesh in the south. Some of the most promising areas are offshore, including the Krishna Godavari basin off the east coast. The production record in recent years has been strongly affected first by the start of production at the much-awaited KG-D6 offshore field in 2009, and then by its faster than expected decline because of reported subsurface complexity. This has contributed to an overall decrease in Indian gas output since 2011. Production of conventional gas reached 34 bcm in 2013 and was supplemented by LNG imports via four regasification terminals. The majority state-owned gas company, GAIL, is the largest player in the midstream and downstream gas market.

In addition to conventional gas resources, India also has large unconventional potential, both from coalbed methane (CBM) and shale gas. Commercial production at scale is still some way off, although CBM activity is starting to gain momentum, with a number of private companies, including Reliance and Essar, stepping up their involvement. In the case of shale gas, the government approved in 2013 an exploration policy that allows the two national companies – ONGC and OIL – to drill for shale resources in their existing blocks. However, upstream gas development in India continues to face a number of significant hurdles: a key issue is the price available to domestic producers (see section on energy prices and Chapter 3).

Hydropower

India has significant scope to expand its use of hydropower: its current 45 GW of installed capacity (of which over 90% is large hydro) represents a little under a third of the assessed resource. Much of the remaining potential is in the north and northeast. A further 14 GW are under construction, although some of these plants have been delayed by technical or environmental problems and public opposition. If developed prudently, hydropower can bring multiple benefits as a flexible source of clean electricity, and also as a means of water management for flood control, irrigation and domestic uses. It can also enable variable

11. This two-tier structure is the result of a subsidy system that compensated state refiners for losses on domestic sales but from which private sector refiners were excluded, leading the latter to focus on international markets. With the removal of subsidies on domestic transport fuels the situation is expected to change, and private refiners are expected to gain domestic market share.

renewables to make a greater contribution to the grid. However, its development has lagged well behind thermal generation capacity, leading to a consistent decline in its share of total electricity output. Capacity additions and generation have routinely fallen short of the targets set in successive government programmes, while the objective of bringing in private investors has likewise proved difficult to realise.

High upfront costs, the need for long-term debt (which is quite limited in India's capital markets) and consequent difficulties with financing have been a major impediment to realising India's hydropower potential. Much of the potential is in remote areas, necessitating new long-distance transmission lines to bring power to consumers. Adequate and efficient project planning and supervision is another hurdle, notably the challenge of evaluating and monitoring environmental impacts (including long-term water availability and potential seismic risks), ensuring adequate public involvement and acceptance, and assessing the effect of multiple projects (often in different states) on individual river systems. Some hydropower projects have faced very long environmental clearance and approval procedures, as well as significant public opposition arising largely from resettlement issues and concern over the impact on other water users. Some of these concerns can be reduced by undertaking small-scale projects: India has an estimated potential 20 GW of small hydro projects (up to 25 megawatt [MW] capacity) (MNRE, 2015). As of 2014, 2.8 GW of small hydro (less than 10 MW) had been developed.[12] Such projects are particularly well-suited to meet power requirements in remote areas.

Bioenergy

Bioenergy accounts for roughly a quarter of India's energy consumption, by far the largest share of which is the traditional use of biomass for cooking in households. This reliance gives rise to a number of problems, notably the adverse health effects of indoor air pollution. India is also deploying a range of more modern bioenergy applications, relying mainly on residues from its large agricultural sector. There was around 7 GW of power generation capacity fuelled by biomass in 2014, the largest share is based on bagasse (a by-product of sugarcane processing) and a smaller share is cogeneration based on other agricultural residues. The remainder produce electricity via a range of gasification technologies that use biomass to produce syngas, including small-scale thermal gasifiers that often support rural small businesses. Although modern bioenergy constitutes only a small share of energy use at present, Indian policy has recognised – with the launch of a National Bioenergy Mission – the potential for modern bioenergy to become a much larger part of the energy picture especially in rural areas, where it can provide a valuable additional source of income to farmers, as well as power and process heat for consumers.

Biofuels are another area of bioenergy development in India, supported by an ambitious blending mandate, dating back to 2009, that anticipates a progressive increase to a

12. The Ministry of New and Renewable Energy defines small hydro as up to 25 MW while the World Energy Model (WEM) used by the *World Energy Outlook* defines small hydro as less than 10 MW. The 2.8 GW refers then to the WEM definition.

20% share for bioethanol and biodiesel by 2017. Implementation has thus far been slower than planned: the present share of bioethanol – mostly derived from sugarcane – remains well under 5% and progress with biodiesel has been even more constrained. The main concern over biofuels – and some other forms of bioenergy – is the adequacy of supply: land for biofuels cultivation can compete with other uses, as well as requiring water and fertilisers that may be limited and is required in other sectors.

Wind and solar

From a low base, modern renewable energy (excluding hydropower) is rapidly gaining ground in India's energy mix as the government has put increasing emphasis on renewable energy, including grid-connected and off-grid systems. Wind power has made the fastest progress and provides the largest share of modern non-hydro renewable energy in power generation to date. India has the fifth-largest amount of installed wind power capacity in the world, with 23 GW in 2014, although investment has fluctuated with changes in subsidy policies at national and state level. Key supporting measures have included a generation-based financial incentive (a payment per unit of output, up to certain limits) and an accelerated depreciation provision. A scheme of renewable purchase obligations also exists, requiring that a certain percentage of all electricity should be sourced from wind, solar and other renewables, but the operation of this scheme has been undercut (and not enforced in some cases) by the financial state of many distribution companies.

Solar power has played only a limited role in power generation thus far, with installed capacity reaching 3.7 GW in 2014, much of this added in the last five years. However, India began to put a much stronger emphasis on solar development with the launch in 2010 of the Jawaharlal Nehru National Solar Mission, the target of which was dramatically upgraded in 2014 to 100 GW of solar installations by 2022, 40 GW of rooftop solar photovoltaics (PV) and 60 GW of large- and medium-scale grid-connected PV projects (as part of a broader 175 GW target of installed renewable power capacity by 2022, excluding large hydropower). The dependence of national targets on supportive actions taken at state level is underlined by the fact that four states (Gujarat, Rajasthan, Madhya Pradesh and Maharashtra) account for over three-quarters of today's installed capacity. Rooftop solar also has the potential to become a more important part of India's solar portfolio, particularly where it can minimise or displace expensive diesel-powered back-up generation.

While the promise is undeniable, renewable energy faces, like other energy source, structural, governance and institutional challenges. Though costs for solar and wind are declining, in most cases the technologies do not yet warrant investment in India (as in most other countries) without some form of subsidy. Fiscal incentives and policy support are strong at the moment, but this is a source of uncertainty, especially when juxtaposed with the financial difficulties faced by local distribution companies that are often obliged to absorb the extra cost. The need for land and additional transmission and distribution infrastructure (which India is trying to address via the concept of "green energy corridors") could likewise constrain progress. Given the priority in Indian policy to develop the domestic manufacturing sector, the outlook is also contingent to a degree on the local availability of equipment, such as solar panels and wind turbines, where India has lost ground to lower cost producers. In China, for example, the cost of locally produced solar modules and cells is 25-50% lower than in India.[13]

Nuclear power

India has twenty-one operating nuclear reactors at seven sites, with a total installed capacity close to 6 GW. Another six nuclear power plants are under construction, which will add around 4 GW to the total. The operation of the existing nuclear fleet has been constrained in the past by chronic fuel shortages, in 2008 the average load factor was as low as 40%. This constraint was eased after India became a party to the Nuclear Suppliers' Group agreement in 2008, allowing access not only to technology and expertise but also reactor parts and uranium. The average plant load factor rose to over 80% in 2013 (DAE, 2015).

Though the current share of nuclear power in the generation mix is relatively small at 3%, India has ambitious plans to expand its future role, including a long-term plan to develop more complex reactors that utilise thorium – a potential alternative source of fuel for nuclear reactors. India has limited low-grade uranium reserves, but it has the world's largest reserves of thorium: developing a thorium fuel cycle will though require a range of tough economic, technical and regulatory challenges to be overcome.

The nuclear industry in India is also subject to the broader challenges that are facing the worldwide nuclear industry, including project economics, difficulties with financing and the implications of the Fukushima Daiichi accident in Japan for public acceptance of new projects. India has struggled to attract the necessary investment and to gain access to reactor technology and expertise, with the Civil Liability Nuclear Damage Act of 2010 widely seen as deterring potential suppliers (especially Japanese and US companies). However, the United States and India reached an understanding on nuclear liability issues early in 2015 that may facilitate US investment in Indian nuclear projects.

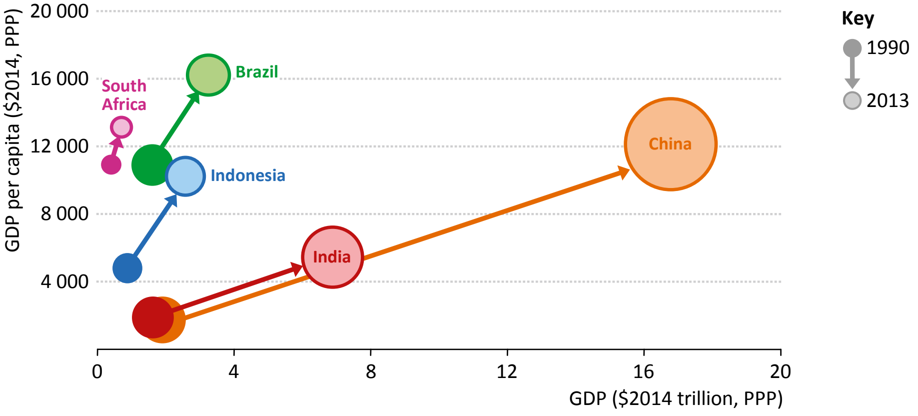
Factors affecting India's energy development

Economy and demographics

The pace of economic and demographic change is a vitally important driver of India's energy sector. Since 1990, India's economy has grown at an average rate of 6.5% a year, second only to China among the large emerging economies, and two-and-a-half-times the global average (if both these countries are excluded). This propelled India beyond Japan in 2008, to become the third-largest economy in the world, measured on a PPP basis. India alone has accounted for over 9% of the increase in global economic output since 1990.

13. Further details of developments in the relative cost of manufacturing renewables technologies can be found in Chapter 9 of the *World Energy Outlook 2015*, (IEA, 2015).

Figure 1.10 ▷ GDP per capita and total GDP for selected countries, 1990 and 2013



Note: PPP = purchasing power parity.

In the period since the early 1990s, the poverty rate (measured as the proportion of the population making less than $1.25/day in PPP terms[14]) fell by more than half, from almost 50% to less than 25%. In the eight years 2004-2011, more than 180 million people in India were lifted out of extreme poverty. Despite this progress, income per capita is still low and a gap has emerged between India and its counterparts among the BRICS (Brazil, Russia, India, China and South Africa). Though starting off at similar levels in the early 1990s (in PPP terms), average income per capita in China is now more than double that in India (Figure 1.10). Furthermore, although extreme poverty has been reduced, income inequality has increased in India, with the poorest quartile of society earning a smaller share of total income than they did in 1990.

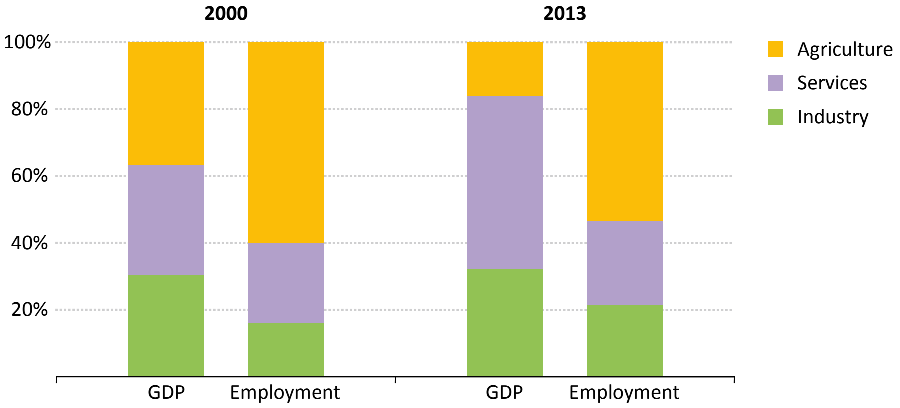
The services sector has been the major driver of growth in India's economy, accounting for around 60% of the increase in GDP between 1990 and 2013. This is rooted both in a robust increase in the supply of services but, crucially, also in the increasing share of high-value segments including financial intermediation, information and communications technology, and professional and technical services, which have enabled total factor productivity in the services sector to more than double. However, despite its dominant share in the economy, the services sector employs only around one-quarter of the labour force. The agricultural sector, with less than 20% of GDP (compared with just over 35% in 1990), continues to account for around half of total employment (Figure 1.11).

The services-led growth that India has enjoyed since the early 1990s differs from the path of economic development in many other countries, since it was not preceded by an initial strong push from the manufacturing sector. The government has expressed its intention

14. The benchmark for absolute poverty was adjusted upwards by the World Bank in late September 2015 to $1.90 per day.

to re-balance the economy and in 2014 announced the “Make in India” initiative, with the intention of increasing the share of manufacturing in GDP to 25% by 2022, creating 100 million jobs in the process. The extent to which this objective is realised will affect India’s energy development in two ways. First, mining, oil and gas, renewables and power generation have all been identified as clusters for industrial development, so any success will have implications for energy supply. Second, any change in the share of industry in the economy, and the materials-intensity of future economic growth, will have profound effects on the levels of energy demand. Urbanisation and the build-up of a manufacturing base, including the necessary energy infrastructure, will require significant inputs from the basic materials industry, including steel, cement and chemicals, which are all highly energy-intensive.

Figure 1.11 ▷ Composition of GDP and employment structure in India



Since 1990, India’s population has grown by over 380 million people, a number greater than the total population of the United States and Canada together. This includes a near-doubling of the urban population, reflecting the transition away from agricultural employment. Population growth is expected to remain high; India is set to overtake China as the most populous country in the world before 2025 (UNPD, 2015). India’s large and growing population is often regarded as one of its major assets; it is relatively young, with almost 60% (around 700 million people) under the age of 30, a large and potentially very vibrant workforce. The large domestic market can also act as a natural driver for economic growth, with levels of private consumption currently around two-and-a-half-times as large as exports. The flip side of this demographic dividend is the likely strain on the country’s infrastructure and resources. Water stresses that are already evident in some regions will be exacerbated and create new challenges in relation to food and energy security, and there will be a need to create one million new jobs each month to absorb the new entrants to the labour market.

Policy and institutional framework

The direction that national and state policies take, and the rigour and effectiveness with which they are implemented, will naturally play a critical role in India's energy outlook. Clarity of vision for the energy sector is difficult to achieve in India, not least because of the country's federal system and complex institutional arrangements. However, the drive for a more coherent and consistent energy policy has been a long-standing priority, typified by the Integrated Energy Policy 2008, the National Action Plan on Climate Change and the co-ordination efforts of the Planning Commission (now the National Institution for Transforming India, [NITI Aayog]), all aided by consistent improvements in the quality of Indian energy data (Box 1.3). An energy scenario modelling exercise has also been launched, the India Energy Security Scenarios, overseen by NITI Aayog.[15] More recently, the submission of India's Intended Nationally Determined Contribution (INDC) on 1 October 2015 was a milestone in both India's energy and its environmental policy.

India shares the overarching aim of energy policy throughout the world: to provide secure, affordable and universally available energy as a means to underpin development, while addressing environmental concerns. The administration in place since 2014 has given greater definition to many aspects of energy policy, while also seeking to give more rights and responsibilities to the individual states. Some key aspects of the emerging energy vision are:

- A commitment to the efficient use of all types of energy in order to meet rapidly growing demand. In the power sector, the decision to increase the target for renewables to 175 GW by 2022 (including the expansion of solar generation capacity to 100 GW) has attracted a lot of attention; but there is also, for example, a volumetric target for India to produce 1.5 billion tonnes of coal by 2020. Efficiency gains as well as production increases underlie India's energy security objective of reducing reliance on fossil-fuel imports by 10%.
- A sharpened focus on achieving universal access to modern energy, including the objective of supplying round-the-clock electricity to all of India's population. This is being accompanied by a reorientation of energy subsidy programmes, away from price controls and towards financial payments to the most vulnerable parts of society.[16]
- A drive for market-oriented solutions and increased private investment (including foreign investment) in energy, both through some energy-specific reforms (e.g. to licensing regimes) and via a general drive to simplify and deregulate the business environment.
- A pledge to pursue a more climate-friendly and cleaner path than the one followed thus far by others at corresponding levels of economic development. India's INDC includes the twin energy-related commitments to increase the share of non-fossil fuel

15. See *www.indiaenergy.gov.in*.

16. This is linked with the implementation of the Aadhaar system, a direct benefit transfer scheme introduced in 2013 that links a personal identification number to a bank account (see section on pricing).

power generation capacity to 40% by 2030 (with the help of transfer of technology and low cost international finance) and to reduce the emissions intensity of the economy by 33-35% by the same date, measured against a baseline of 2005.

Box 1.3 ▷ India's energy sector data

Energy data in India is available from a variety of sources, with the main ministries all collecting data within their areas of responsibility: for example, the Central Electricity Authority, under the Ministry of Power, takes the lead in providing statistical information on the electricity sector. Selected data from these sources are compiled by the Central Statistics Office into an annual "Energy Statistics" publication. The latest version covers the period to 31 March 2014, meaning that the latest calendar year for which there is full coverage is 2013 (most Indian data are available for fiscal years, which run from April to March) (CSO, 2015).

Data from these official energy institutions and from the Central Statistics Office are the bedrock of the statistical information used in this report. In some cases, however, the way that the data are collected and reported does not match exactly the IEA's reporting requirements, so certain additional numbers in the IEA databases are taken from secondary sources or estimated by analysing related indicators. This applies, for example, to the use of solid biomass as an energy source, the use of back-up or off-grid generation and the split of oil product demand across end-use sectors. Differences in the definitions used and in fiscal years versus calendar year reporting, can also lead to some adjustments being made.[17] In some areas, the *World Energy Outlook* uses a single global source in order to ensure a consistent underlying methodology: this is the case for installed thermal power generation capacity, which is drawn for all countries from a dataset maintained by Platts.

Achievement of these aims is naturally contingent on the broader political and institutional context. India is a federal, democratic country in which regional and local politics and governments play a very important role, via the 29 constituent states and 7 union territories (their role is reflected in the bi-cameral national parliamentary structure, where the lower house, elected by direct popular vote, sits alongside an upper house, representing the states and territories). The constitution divides power between the central and state governments, as well as defines a category of subject areas for which there are concurrent responsibilities. The central government has exclusive competence over inter-state trading and commerce, as well as mineral and oil resources, nuclear energy and some national taxes, e.g. on income. States have jurisdiction over water issues and land rights, natural gas infrastructure, and many specific areas of taxation, e.g. on mineral rights or the

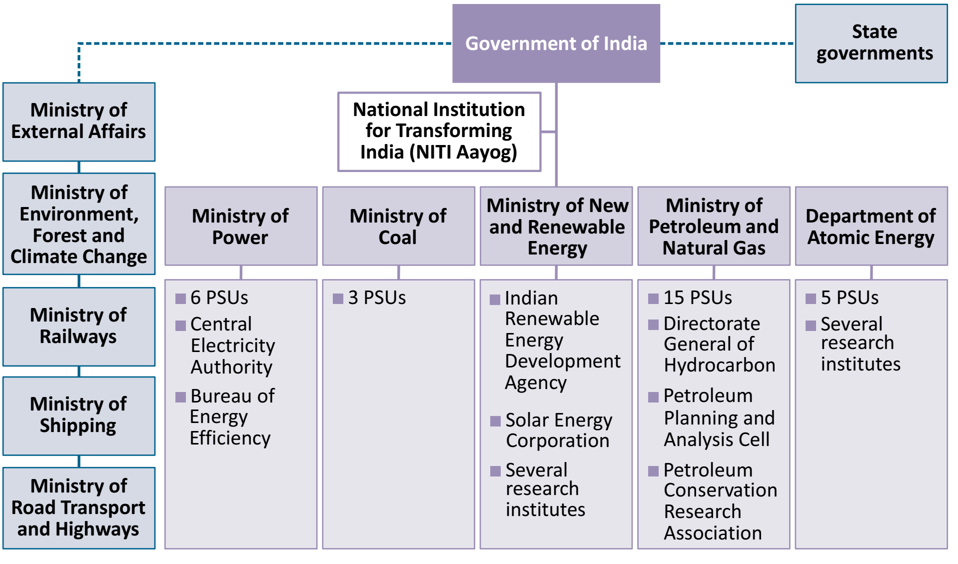
17. For example, the Coal Directory of India uses a national classification scheme for coal grades (depending on their energy content) different from that used by the IEA statistical services. This can result in differences in supply and demand values when expressed in million tonnes of coal equivalent.

consumption or sale of electricity. Concurrent powers include electricity and forestry, as well as economic and social planning, and labour relations.

India's federal structure puts a premium on constructive relations between states and the central government, but also risks duplication and inconsistent decision-making. The model being promoted by the new administration is one of co-operative federalism, which involves increased devolution in certain areas (e.g. a higher regional share of hydrocarbon revenues in some cases) as well as a wider set of regional responsibilities (e.g. for timely implementation and approval of the state-level clearances required for investment projects). There is also a greater accent on tailoring policies and resource use, particularly in the power sector, to the specificities of individual regions and states. Maintaining independent regulatory bodies, free of political interference (for example, as envisaged in the 2003 legislation reforming the power sector), is a challenge at all levels.

The risk of fragmented decision-making also applies at the national level itself, as there is no single body charged with formulating and implementing a unified energy policy. India has several ministries and other bodies, each with partial responsibility for aspects of energy policy and the related infrastructure (Figure 1.12). Effective co-ordination has been improved by the appointment of a single Minister for Power, Coal, New and Renewable Energy, although the individual ministries themselves continue to exist as separate entities. The institutional structure requires constant effort – not always successful – to achieve co-ordination and resolve disputes.

Figure 1.12 ▷ Main institutions in India with influence on energy policy



Notes: PSU = Public sector undertaking (state-owned enterprise). Other ministries with responsibilities relevant to the energy sector include the Ministry of Urban Development, Ministry of Water Resources, Ministry of Agriculture, Ministry of Finance and the Department of Science and Technology.

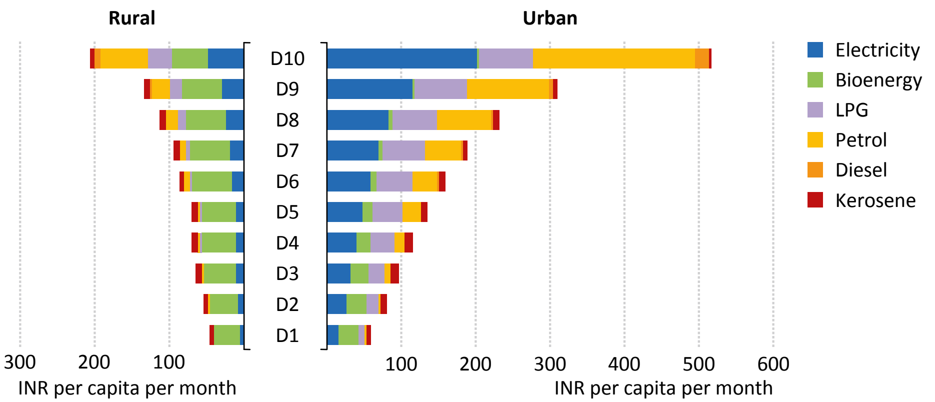
Source: Adapted from (IEA, 2012).

Energy prices and affordability

Expenditure

The relationship between income levels, energy prices and energy expenditure is fundamental to the evolution of India's energy system. As one would expect, energy consumption increases with income, with the wealthiest 10% of the population accounting for around a quarter of all household energy expenditure, although the poorest segments spend a greater proportion of their income on energy. But the level of consumption and the fuel choice are also affected by location: household expenditure on energy is, on average, almost two-and-a-half-times higher in urban centres than in rural areas, and the most affluent among the urban population spend more than eight-times as much on energy as the poorest, whereas in rural areas they spend four-and-a-half-times as much (Figure 1.13).

Figure 1.13 ▻ Per-capita energy expenditure by location and income in India



Notes: INR = Indian rupees. The income ranges are by decile (i.e. 10% slices) of the rural and urban population, with D10 being the most affluent 10% and D1 the poorest.

Source: Ministry of Statistics and Programme Implementation (2012).

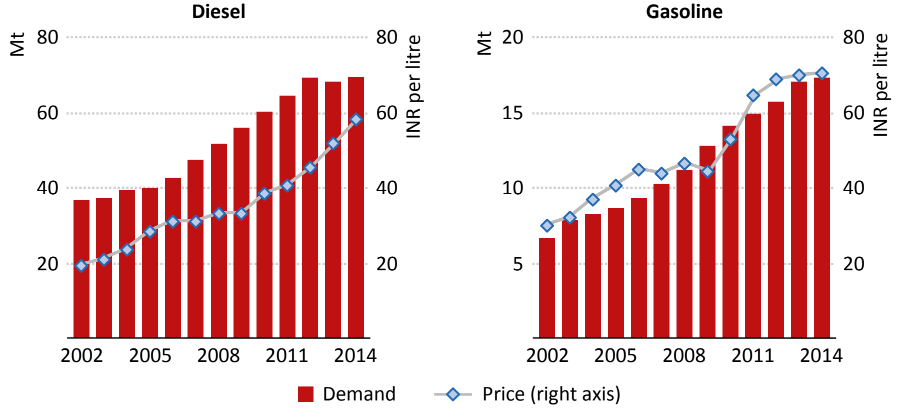
The expenditure pattern across the income groups reflects both an increase in energy consumption as people become more affluent and a switch in fuels, away from bioenergy and kerosene and towards LPG and electricity. In urban areas, spending on bioenergy and kerosene decreases drastically higher up the income groups. Bioenergy and kerosene account for almost 60% of energy expenditure among the poorest income group, but only roughly 1% among the wealthiest group in which 85% of energy expenditure is for electricity and transport fuels.

The pattern is different in rural areas. Here, spending on bioenergy increases as income increases (for all but the wealthiest 20%), driven by a rise in consumption, but also because the poorer segments of society typically collect fuelwood rather than pay for it, an inclination that gradually decreases with increasing levels of wealth. The pattern of expenditure of the most affluent decile in rural areas is significantly different from that of lower income groups, resembling the switch that is observed in urban centres, albeit in a more limited way. Across income levels, rural spending on electricity accounts for around 20% of energy expenditure (compared with almost 40% in urban areas). Rural expenditure is constrained by a lack of access, particularly among the poorest segments of rural communities.

Energy prices

India has made significant moves towards market-based pricing for energy in recent years: gasoline (in 2010) and diesel (2014) prices have both been deregulated, and successive governments have made efforts to ensure that electricity and natural gas prices better reflect market realities. End-use electricity tariffs for most consumers nonetheless remain below the cost of supply. Reform of kerosene and LPG pricing has been much slower, reflecting the role that these fuels play in providing lighting and cooking fuels to the poorest segments of society. As a major consumer and importer of oil, India has also been one of the main beneficiaries of the fall in the oil price since 2014 (see Box 2.2 in Chapter 2).

Figure 1.14 ▷ Diesel and gasoline prices and demand, 2002-2014



Notes: Mt = million tonnes; INR = Indian rupees. Year denotes fiscal year, starting in April and ending in March.
Source: Petroleum Planning and Analysis Cell (2015).

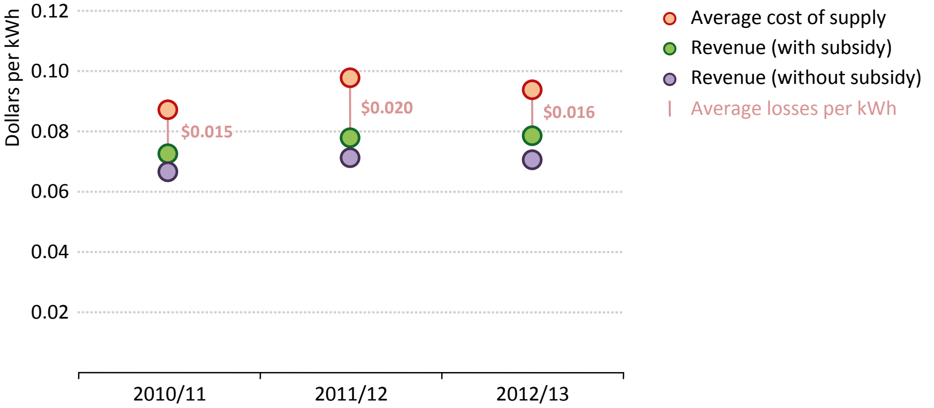
Diesel is the most widely consumed petroleum product in India, accounting for around 40% of total oil product consumption. In 2002-2010, the price of diesel was, on average, 70% that of gasoline and this price gap widened when gasoline prices were deregulated in 2010. Price differentials have recently lessened with the removal of diesel subsidies, resulting in diesel consumption flattening as consumer preferences shift towards gasoline (Figure 1.14). During the period in which transport fuels were subsidised, the benefits accrued disproportionately to the wealthiest strata of society: prior to the deregulation of diesel prices, the bottom two income deciles benefited to the tune of 20 Indian rupees (INR) per capita per month on average from subsidies, while the top two deciles received around INR 120 per capita per month (Anand, 2013). Where subsidies to oil product consumption remain, as in the case of LPG, the government is committed to make them more efficient: the "Aadhaar" system, coupled with recent efforts to spread banking service access to all, will increasingly allow the authorities to make a monetary payment directly to eligible consumers, after they have purchased gas cylinders at market prices. The government also launched a "Give it up" campaign to encourage the wealthiest consumers to abandon their LPG subsidy. As of September 2015, over three million Indians had voluntarily given up the subsidy.

The Indian gas market consists of two segments: for domestically produced gas, the price is defined by the government, as are the priority uses (city gas for households and transport, fertiliser plants, grid-connected power plants) which are entitled to gas at this lower price. After a long debate, in October 2014 the government introduced a new pricing formula, linked to a basket of international prices and applicable to most domestically produced gas; this resulted in a price increase from the earlier $4.2 per million British thermal units (MBtu) to around $5.6/MBtu, although this has since come down because of the subsequent fall in the reference prices. The new arrangements have kept the price in a range acceptable to domestic gas-consuming sectors, but many gas-producing companies argue that they do not offer sufficient incentive to bring forward new investment in exploration and production in India, particularly in offshore blocks (see Chapter 3). Imported LNG is available at contracted prices that can be significantly higher; there have been proposals to pool LNG with domestically produced gas to make it more accessible to domestic users as well as a subsidy scheme to increase consumption of imported LNG in the power sector.

As noted in the electricity section, average end-use electricity tariffs in India do not adequately reflect the cost of electricity supply, with government subsidies covering a part of the gap and the rest being absorbed as losses by state-owned distribution utilities (Figure 1.15). According to national policy guidelines, the state electricity regulatory bodies are supposed to set tariffs within a 20% range of the average cost of supply, but this is rarely the case. As of 2010-11, with the exception of three states (Gujarat, Maharashtra and West Bengal), average tariffs for consumers were less than 80% of the cost of supply (TERI, 2015).

The consumption changes spurred by the recent increase in diesel prices relative to those of gasoline reflect the conventional wisdom that higher prices can act as a brake on demand, spurring consumers to switch fuels, reduce their consumption or opt for more efficient technologies. The inverse relationship, where low tariffs lead to inefficient use of both electricity and water, is evident in the agricultural sector, which accounts for more than one-fifth of final electricity consumption but only 8% of revenue for the utilities.

Figure 1.15 ▷ Average cost of electricity and average revenue in India, 2010-2013



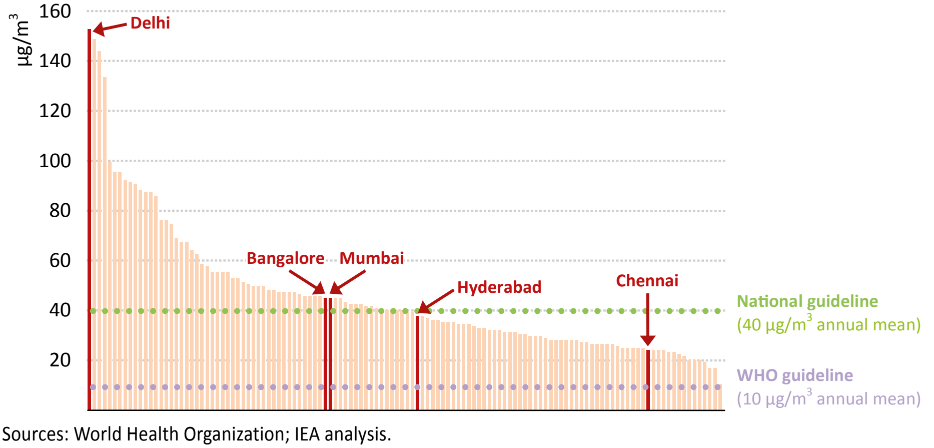
Sources: Power Finance Corporation; IEA analysis.

Social and environmental aspects

Local air pollution

Rapid economic growth and urbanisation create a number of pressures on communities and the wider environment. These can originate from the need to meet growing demand for energy and minerals that increase competition for land, water and other resources, as well as the polluting by-products of the subsequent growth. India is burning more fossil fuels and biomass than it has at any other time in the past, releasing more pollutants, including fine particulate matter ($PM_{2.5}$)[18] and sulphur and nitrogen oxides, into the air.

Figure 1.16 ▷ Average annual particulate matter concentration in selected cities in India



Sources: World Health Organization; IEA analysis.

18. $PM_{2.5}$ refers to particulate matter less than 2.5 micrometres in diameter; these fine particles are particularly damaging to health as they can penetrate deep into the lungs when inhaled.

In addition to the problem of indoor air pollution linked to the traditional use of biomass as a cooking fuel, the deteriorating air quality in growing urban centres is becoming an alarming issue for India (Figure 1.16). Of the 124 cities in India for which data exist, only one, Pathanamthitta (with a population of 38 000), meets the World Health Organization guideline for $PM_{2.5}$ concentrations. Delhi exceeds this guideline by fifteen-times. India has 13 of the world's 20 most-polluted cities and an estimated 660 million people in areas in which the government's own national air quality standards are not met. It is estimated that life expectancy, as a result, is reduced by 3.2 years for each person living in these areas.

Land

The welfare of India's rural population, which is 850 million strong and accounts for almost 70% of the total population, is closely linked to the amount of land they have available for productive use. Land acquisition for public or private enterprises wishing to build infrastructure, from roads and railways to power plants and steel mills, is therefore an issue fraught with social and political sensitivity. Legislative changes introduced in 2013 introduced stringent procedural requirements for land acquisition, defining compensation payments and rehabilitation and resettlement benefits and stipulated that potential developers in the private sector would need to secure the consent of 80% of affected families in the case of land acquisition (70% for acquisitions by public-private partnerships). There have since been attempts to amend this legislation, but finding an appropriate balance between the drive to push ahead with infrastructure projects, on the one hand, and the rights of local communities, especially farmers, on the other, is proving difficult. In the absence of a resolution to this issue, obtaining the required statutory clearances related to community rights, environmental protection and sustainable development has been a major cause of delay. At end-2014, infrastructure projects valued at around 7% of GDP were stalled for these reasons (OECD, 2014). Projects in the energy sector are particularly susceptible to delay: detailed analysis of projection applications showed that the clearance process for some 40-60% of projects in thermal power, hydropower, coal mining and nuclear power sectors went beyond the statutory time limits (Chaturvedi et.al, 2014).

Water

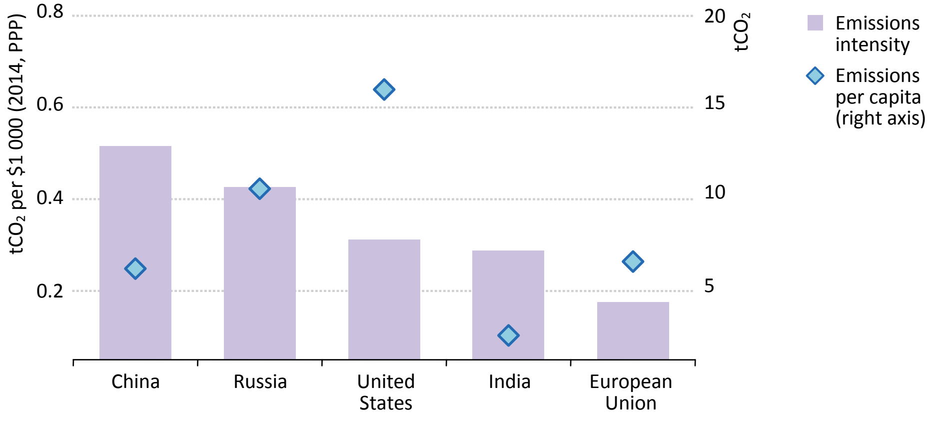
High rates of population and economic growth, along with highly inefficient patterns of water use in the agricultural sector, are putting severe strain on India's water resources. With renewable water resources of some 1 130 cubic metres per capita in 2013, India has now passed the defined threshold for "water stress" (1 700 cubic metres per capita). This has major implications for the energy sector: more than 70% of India's power plants, for example, are located in areas that are water stressed or water scarce (WRI, 2014) and India's warm temperatures and the poor quality coal used in the bulk of its power plants add to their cooling requirements. Global climate change could exacerbate these stresses.

Around 90% of India's water withdrawal is for use in agriculture and livestock, often extracted by tube wells powered from the grid and drawing from groundwater reserves. Subsidised electricity tariffs for agricultural users and a lack of metering have led to hugely inefficient consumption of both electricity and water: in 2010, more water was withdrawn in India for agricultural use alone than for all purposes in China. A number of national and state-level initiatives have sought to encourage more efficient water use, via metering, tariff reform (linked to more reliable supply) and changes to agricultural practices. Plans to introduce more efficient equipment, including solar-powered groundwater pumps, while relieving some pressures on the grid, could reduce incentives for water conservation unless they are accompanied by the introduction of systems that use water more efficiently, such as drip irrigation networks.

Carbon-dioxide emissions

India's CO_2 emissions can be seen through two lenses. Calculated on a per-capita basis, emissions are extremely low, standing at just one-quarter of China's and the European Union's and one-tenth the level in the United States (Figure 1.17), while India also accounts for only a small share of cumulative historical GHG emissions. On the other hand, India is the third-largest country in volume terms of CO_2 emissions in the world, behind only China and the United States. Heavy dependence on coal for power generation and the use of inefficient subcritical plants to burn it push up the carbon intensity of India's power sector to 791 grammes of carbon dioxide per kilowatt-hour (g CO_2/kWh), compared to a world average of 522 g CO_2/kWh.

Figure 1.17 ▷ Carbon intensity of GDP and energy-related CO_2 emissions per capita in selected regions, 2013

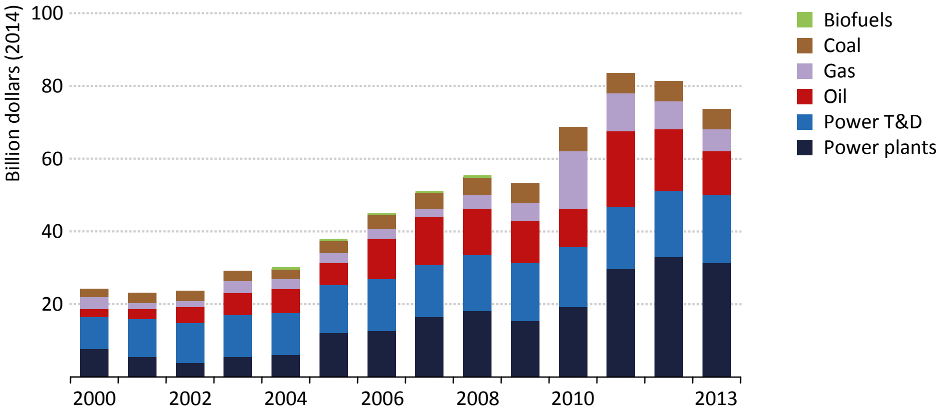


Note: tCO_2 = tonnes of carbon dioxide; PPP = purchasing power parity.

Investment

Since 2000, we estimate that investment in energy supply in India has increased substantially, reaching almost $77 billion on average since 2010 (Figure 1.18). The power sector absorbs the largest share, spurred by the rapid increase in demand as encouraged by the liberalisation agenda launched by the landmark Electricity Act in 2003. Maintaining a rising trend in infrastructure spending, especially energy sector spending, is a major government policy priority. India's government aims to increase investment in infrastructure (broadly defined, including communications, road, rail and energy networks, as well as social areas such as schools and hospitals) to 8.2% of GDP, from roughly 7.2% in 2007-2011. More than a third of this $1 trillion in infrastructure spending is to go to electricity, renewable energy, and oil and gas pipeline projects, with around half from private investment.[19] Relieving infrastructure bottlenecks, particularly those related to poor road and rail infrastructure, inefficient ports and unreliable electricity supply, is widely recognised as essential to meet India's economic growth and development ambitions (IMF, 2015).

Figure 1.18 ▷ Energy supply investment by type, 2000-2013



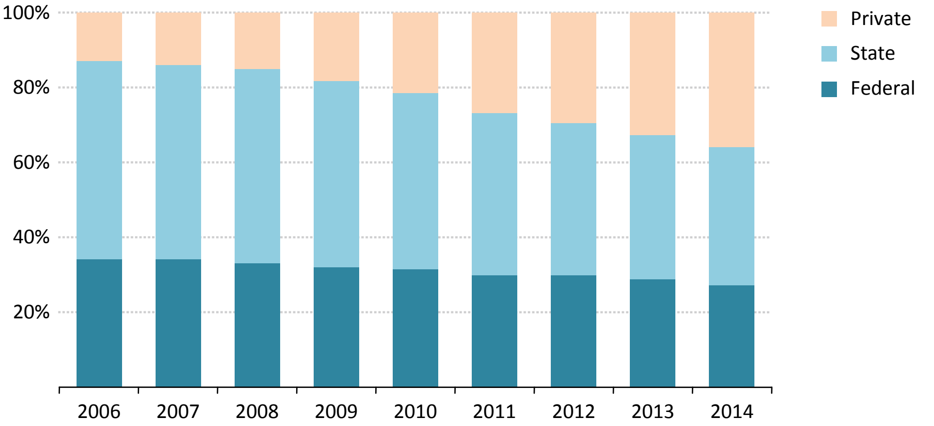
Note: T&D = transmission and distribution.

As the Indian government has recognised, public funds sufficient to support the necessary investment projects in the energy sector cannot be taken for granted, in the face of increasing competition from other areas of public spending (including healthcare, pensions, education, etc.). So meeting the country's investment needs will require the mobilisation of increasing amounts of private capital, including foreign direct investment (FDI). Access to such investment opportunities by the private sector though is uneven across the Indian energy economy and a number of broader impediments to attracting investment persist, such as the complex regulatory environment, in relation to which the World Bank has ranked India 142 out of 189 countries in terms of ease of doing business. Despite these impediments, India's vast potential puts it high on the list of prospective destinations for foreign investment, ranking third behind China and the United States. Furthermore, 2014 saw a significant increase in FDI inflows, which rose by 22% compared to the previous year, to a total of over $34 billion (UNCTAD, 2015). Preliminary numbers for FDI in 2015 show a further substantial increase.

19. Since 1990, investments worth $330 billion have been made through public-private partnerships, of which over 40% were in the energy sector. In the last five years, India has had the highest amount of infrastructure investment co-financed with the private sector among the low and middle income countries (OECD, 2014).

Since the late 1990s, steps have been taken to deregulate the oil and gas sectors, notably successive bidding rounds held under the New Exploration Licensing Policy, which have been open to a range of private players. However, these two sectors remain dominated, in practice, by a handful of state concerns and the process of opening the coal sector to private investment is only just beginning. The power generation sector has been open to private participation for some time and the government has offered a range of fiscal incentives to increase the attractiveness of projects. Since 2006, 6 GW out of every 10 GW of net capacity added to the grid has been financed by private investors, whose share of generation has increased quickly, to reach more than one-third of the total (Figure 1.19). Private sector involvement in the distribution side of the power system is much more limited. Presently the distribution utilities are largely state-controlled and administered, and the priority given to regional social sensitivities often contributes to the under-recovery of costs across the sector.

Figure 1.19 ▷ Power generation capacity by type of ownership in India



Source: Central Electricity Authority.

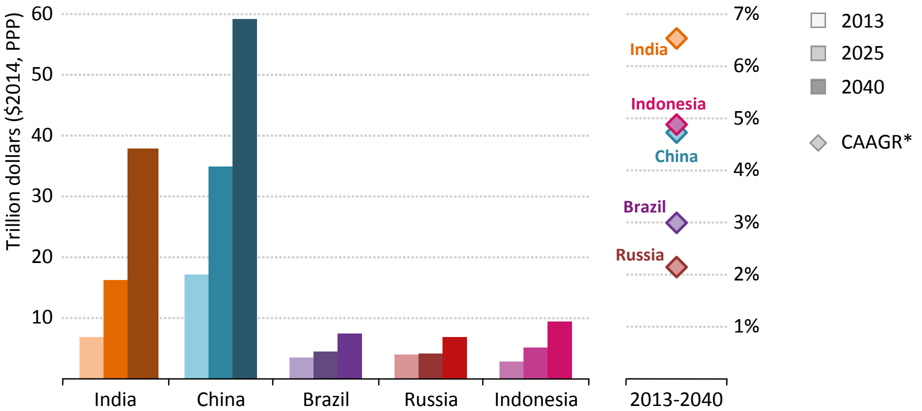
Projecting future developments

The projections for the India energy outlook presented in the following chapters are derived by means of the same overall analytical approach used in the *World Energy Outlook 2015* (see Introduction and scope), but with additional analysis to draw out the policy choices facing India and their implications. The primary focus throughout is the New Policies Scenario – our central scenario – which takes into consideration both existing policies and regulations as well as India's announced policy intentions, such as the targets for renewables and coal and the push to provide universal, reliable electricity access. A cautious view of the pace of implementation is taken throughout the New Policies Scenario, meaning that in the case of India, government targets and objectives are not always reached. This is not a judgement of the feasibility of the government's ambitions or its commitment to them, but reflects our view of the real-life constraints – including regulatory, financial and administrative barriers – that have to be faced. Given the uncertainty that is inherent in long-term projections, we refer in this special focus to a number of alternative scenarios and cases for India, alongside the New Policies Scenario.[20] In Chapter 4, we also develop a case specific to the India special focus, an Indian Vision Case, which reflects the full realisation of India's policy aim to increase the share of manufacturing in its economy, alongside the earlier attainment of energy policy objectives, notably for universal electricity access, and more rapid development of low-carbon energy sources and energy efficiency.

Economic and population growth

India's changing economy is a fundamental driver of its energy development to 2040. In the New Policies Scenario, average annual growth remains at 7.5% until 2020, before slowing gradually to around 6.3% per year by the 2030s. For the entire period to 2040, India's economy grows at a faster rate than any other in the world, by an average of 6.5% per year. By 2040, the economy is over five-times its current size (Figure 1.20). Nearly $1 in every $5 of additional economic output generated in the global economy over the projection period comes from India, leading to a four-fold increase in GDP per capita.

Figure 1.20 ▷ Size of GDP and GDP growth by selected economies, 2013-2040



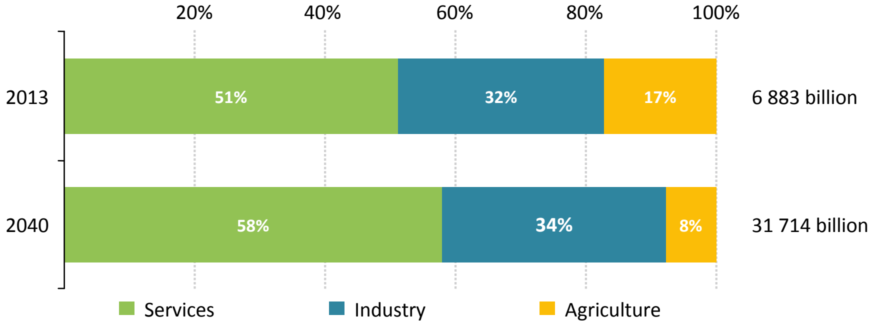
*CAAGR = compound average annual growth rate.

The economic growth path for India is higher than that in the *World Energy Outlook-2014*, by 0.4 percentage points a year, reflecting both a revision of purchasing power parity calculations in 2014 by the International Comparison Program (and subsequently by the International Monetary Fund) and the methodological change adopted by India itself in

20. Three of these scenarios reflect results derived from the global modelling work undertaken for *WEO-2015*, from the Current Policies Scenario, the 450 Scenario, and a Low Oil Price Scenario (which examines the potential implications of an extended period of lower oil prices, compared with the trajectory for oil prices envisaged in the New Policies Scenario – see Chapter 4 of the *World Energy Outlook 2015* [IEA, 2015]).

early-2015. These changes, which affect the base year, mean that the economy today is 36% larger than calculated under the previous methodology. The effect of economic development on the pattern of energy use is not limited to size and the rate of growth, but includes changes to its composition (Figure 1.21). In the New Policies Scenario, though rising less rapidly than targeted by the government, the share of industry in GDP (which includes manufacturing, construction and the extractive industries) does increase over the coming decades, pushed higher by a policy and demand-driven expansion of the manufacturing sector, the "Make in India" initiative. The share of services likewise expands, both at the expense of agriculture.

Figure 1.21 ▷ GDP composition by sector in India, 2013 and 2040 (PPP terms)



Population growth and changes in the population dynamics is another key driver of energy trends. India is already the second-most populous country in the world, with more than 1.25 billion people in 2013. Despite the population growth rate to 2040 slowing to almost half the average rate in 1990-2012 (from 1.6% to 0.9%), growth remains strong enough for India to overtake China as the world's most populous country by 2025, with India's population rising to 1.6 billion by 2040. Almost all of the net growth in the Indian population is absorbed into India's cities: the 315 million increase in India's urban population is roughly equivalent to the entire population of the United States today. The urban share of the total population rises from less than a third to 45%, and means that, at 715 million, there are more people living in cities in India in 2040 than there are in the United States, Japan and Mexico combined. The pattern of urbanisation that India follows has critically important implications for the evolution of its energy consumption.

Energy prices

Energy prices in these projections are largely derived from the international price trajectories described in the Introduction and scope. They vary according to the scenarios under consideration (the Indian Vision Case shares the same international energy price assumptions as the New Policies Scenario). These price assumptions feed through into India's domestic prices, albeit with important qualifications that depend on national policies. The domestic prices of all oil products, except LPG and kerosene, are assumed to be linked to international prices, and those of LPG and kerosene converge towards the international price, reflecting the assumption that policy interventions affecting the price levels of these products are replaced by targeted direct payments to the most vulnerable.

In the case of natural gas, the domestic price level is a weighted average of the price for imported LNG (which, in the New Policies Scenario, remains relatively low over the medium term before rising back to over $9/MBtu in 2020 and almost $13/MBtu by 2040) and the assumed price paid to domestic producers. The latter evolves in line with the new pricing formula introduced in October 2014, which produces a gradually increasing trend; but we assume that this formula is modified to provide a greater incentive for domestic output (this reflects a generic assumption in our modelling that import-dependent countries make efforts to stimulate domestic production and reduce import dependence). Similarly, in the coal sector, we assume a gradual convergence between domestic and international prices in India, driven both by rising domestic mining costs and by the increasing use of market-based instruments to determine prices. In the case of electricity, we assume continued preferential tariffs for certain groups (agricultural consumers, low-income groups) but that, over time, the average end-use tariff reaches a level that remunerates in full the costs of supply, including a reasonable rate of return (accompanied by financial restructuring of the state distribution companies). This reflection of India's policy intentions is a necessary long-term condition for the sound functioning of the electricity market.

Policies

India is undergoing a rapid social and economic transformation, in which strong economic growth, a burgeoning middle class and large-scale urbanisation underpin broader development. Indian policy-makers face the twin challenges of meeting the growing energy requirements to fuel this transformation, while also ensuring that growth is equitable, its fruits shared fairly among India's vast population. As a result, energy security imperatives, including quality, resilience and diversity of supply, but also issues of access, poverty alleviation and affordability are assured to form the foundations of Indian energy policy-making. In terms of the energy mix, India is seeking to balance its development needs with the need to increase the share of low-carbon sources in the energy mix. Its vision provides a continued, important place for coal, alongside a strong push in favour of renewable sources of energy, particularly solar and wind power.

For this special report, we have conducted an extensive review of India's existing policies, regulations and programmes affecting the energy sector, as well as its announced intentions, assessing in each area the record of past achievement and what this might mean for the prospects and speed of future progress. The way that policies shape our projections is discussed in more detail in the chapters that follow. Table 1.2 is a summary of India's domestic policy objectives and assumptions that are taken into account in the New Policies Scenario.[21]

21. The energy-related pledges in India's INDC have not been explicitly included in the assumptions for the New Policies Scenario, as they were announced in October 2015, shortly before publication, but the key underlying policy measures that support the attainment of INDC objectives are taken into consideration.

Table 1.2 ▷ Selected policy assumptions for India in the New Policies Scenario

Cross-cutting policies
■ Priority attached to the energy-related National Missions (on solar energy and enhanced energy efficiency) from the 2008 National Action Plan on Climate Change, as well as the wind power targets.
■ A continued levy on coal (domestic and imported) to support the National Clean Energy Fund.
Energy supply
■ Measures to increase fossil-fuel supply, notably of coal, in order to limit import dependence.
■ Greater encouragement to private investment in energy supply, through loosening of existing restrictions and simplification of licensing procedures.
■ Efforts to expedite environmental clearances and land allocation for large energy projects.
Power sector
■ A strong push in favour of renewable energy, notably solar and wind power, motivated by the target to reach 175 GW of installed renewable capacity (excluding large hydro) by 2022.
■ Enhanced efforts on village electrification and connection of households lacking electricity supply, with the aim to reach universal electricity access.
■ Move towards mandatory use of supercritical technology in new coal-fired power generation.
■ Expanded efforts to strengthen the national grid and reduce losses towards the targeted 15%.
Transport
■ Fuel-efficiency standards for new cars and light trucks starting in 2016.
■ Policy support for biofuels (via blending mandates) and natural gas, hybrid and electric vehicles.
■ Dedicated rail corridors to encourage a shift away from road freight.
Industry
■ Efforts to increase the share of manufacturing in GDP, via the "Make in India" programme.
■ Enhanced efficiency measures in line with the Perform, Achieve and Trade scheme; support for energy audits, as well as new financing mechanisms for energy efficiency improvements.
Buildings
■ Efforts to plan and rationalise urbanisation in line with the "100 smart cities" concept.
■ Moving from voluntary to mandatory appliance standards; application to a wider range of appliances.
■ Extension of the building code and efforts to incorporate it more into local and municipal by-laws.
■ Subsidies for LPG as an alternative to solid biomass as a cooking fuel.
Agriculture
■ Shift towards metered electricity consumption.
■ Continued gradual reforms to energy pricing, promotion of micro-irrigation, groundwater management and crop diversification.

Outlook for India's energy consumption

Is the sky the limit?

Highlights

- In India energy demand is propelled upwards to 2040 by an economy that grows to more than five-times its current size and population growth that makes it the most populous country in the world. Energy consumption more than doubles to 2040, with the rise in coal use making India by far the largest source of growth in global coal demand. A 6 mb/d rise in oil use is likewise the largest projected for any country, as 260 million new passenger vehicles are added to the stock and as LPG substitutes for fuelwood as a cooking fuel in households.

- An extra 315 million people are anticipated to move to India's towns and cities by 2040, and urbanisation underpins many of the changes in energy use, accelerating the switch to modern fuels and the rise in appliance and vehicle ownership, and pushing up demand for steel, cement and other energy-intensive materials. With rising incomes and 580 million additional electricity consumers by 2040, electricity demand in the residential sector increases by more than five-times.

- Industry remains the largest among the end-use sectors, as India's strong demand for infrastructure and consumer goods boosts the outlook for manufacturing. Transport shows the fastest growth, both for freight and for personal mobility. Energy efficiency policies have broadened in recent years to include fuel-efficiency standards for passenger vehicles and an innovative certificate trading scheme in industry, although their coverage across other sectors remains incomplete.

- The power sector is pivotal for India's energy and economic outlook. The poor financial health of the distribution sector has created a cycle of uncertainty for generators, under-investment in infrastructure and poor quality of service in many regions. Regulatory and tariff reform, a robust system of permitting and approvals, grid strengthening and major capacity expansion are pivotal to allow power supply to catch up and keep pace with burgeoning demand, which, boosted by new connections to the grid, increases at 4.9% per year.

- Installed power capacity surges from below 300 GW today to over 1 000 GW in 2040. Nearly half of the net increase in coal-fired generation capacity worldwide occurs in India, although the shift to more efficient technologies brings average coal plant efficiency up from 34% to 38% by 2040. Led by solar and wind power, the rapid growth in renewables, together with a large increase in nuclear capacity, means that these sources account for more than 50% of new capacity brought online. Nonetheless, without stringent policies to control energy-related emissions of gases, dust and fumes from the power sector, industry and transport, India will face a continued deterioration in air quality.

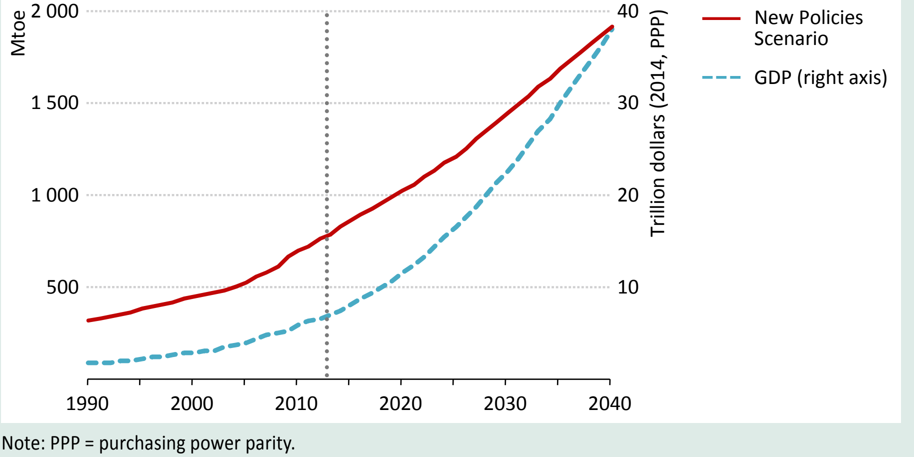
India: a rising force in global energy demand

Energy demand in India is projected to soar over the coming decades, propelled by an economy that grows to reach more than five-times its current size by 2040 and a demographic boom that sees India become the most populous country in the world by 2025. Energy use more than doubles to reach 1 900 million tonnes of oil equivalent (Mtoe) by 2040 (Figure 2.1). The rise in energy use is slower than the increase in gross domestic product (GDP) (Box 2.1), but still represents around one-quarter of the total increase in global energy consumption over the period to 2040. Because of India's strong population growth, consumption per capita falls slightly short of doubling; the level reached in 2040 is around 60% of the global average, up from 33% today.

Box 2.1 ▹ The coupling and decoupling of GDP and energy use in India

The relationship between GDP growth and energy demand is affected by a range of economic, structural and technological factors. Energy demand tends to rise faster than household income as people get access to reliable electricity, prompting purchases of an increasing number of appliances (e.g. lighting, refrigerators, cookers, fans, air conditioners). Energy demand also grows more rapidly than economic output when growth is concentrated in energy-intensive industrial sectors or when people shift their transport habits from trains or buses to individual vehicles. On the other hand, GDP growth from the services sector of the economy tends to require relatively little energy and the relationship between GDP and energy consumption can be further loosened by improvements in energy efficiency. In our projections for India, even with relatively strong growth in manufacturing, it is these latter effects that dominate, with the result of a gradual reduction in the overall energy intensity of India's economy – from 0.11 tonnes of oil equivalent (toe) per $1 000 in 2013 to 0.05 toe per $1 000 in 2040.

Figure 2.1 ▹ GDP and primary energy demand growth in India in the New Policies Scenario



Note: PPP = purchasing power parity.

With energy use declining in many OECD countries and China moving into a much less energy-intensive phase in its development, India is emerging as a major driving force in many areas of global energy. It takes over from China as the largest single source of rising demand both for coal and oil in the period to 2040 and becomes a significant player in a series of other markets, from wind and solar to nuclear, hydropower and natural gas. In the case of coal, the increase in demand in India makes by far the largest contribution to growth in global consumption to 2040. In the case of oil, India accounts for more than 45% of the projected net increase in global consumption. In the electricity sector, demand growth that averages 4.9% per year puts all other major countries and regions in the shade: to meet this demand, India needs to build more than 880 gigawatts (GW) of new power generation capacity over the period to 2040 (for comparison, the entire installed capacity of the European Union is currently around 1 000 GW).

Overview and outlook by fuel

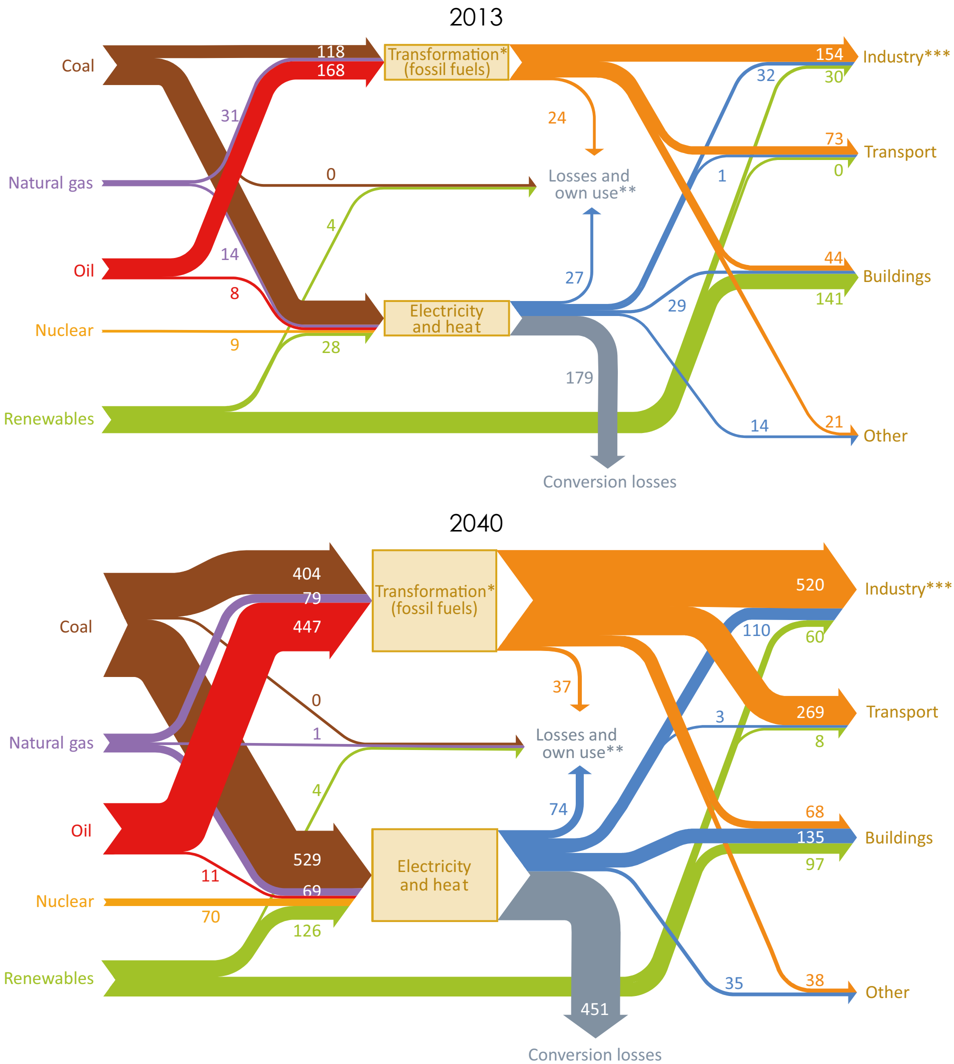
The period of rapid change anticipated for the Indian energy system in the New Policies Scenario does not translate into a dramatic shift in the energy mix (Table 2.1), although there are some noticeable changes in flows through the system as a whole and in the relative weight of the different end-use sectors (Figure 2.2). Coal retains a central position in the mix, increasing its overall share in primary energy from 44% in 2013 to 49% in 2040 (bucking the global trend, where coal declines by four percentage points to 25%), and the shares of oil and gas edge slightly higher. Some of the largest changes however are in the use of non-fossil fuels. On the one hand, the proportion of solid biomass, used mostly in cooking, falls from almost a quarter of primary energy in 2013 to 11% in 2040; but, on the other, there is strong growth in the deployment of modern renewables technologies, led by solar and wind power.

Table 2.1 ▷ Primary energy demand by fuel in India in the New Policies Scenario (Mtoe)

						Shares		2013-2040	
	2000	2013	2020	2030	2040	2013	2040	Change	CAAGR*
Oil	112	176	229	329	458	23%	24%	282	3.6%
Natural gas	23	45	58	103	149	6%	8%	104	4.6%
Coal	146	341	476	690	934	44%	49%	592	3.8%
Nuclear	4	9	17	43	70	1%	4%	61	7.9%
Renewables	155	204	237	274	297	26%	16%	93	1.4%
Hydropower	6	12	15	22	29	2%	1%	16	3.2%
Bioenergy	149	188	209	217	209	24%	11%	20	0.4%
Other renewables	0	4	13	35	60	0%	3%	56	11.0%
Fossil fuel share	*64%*	*72%*	*75%*	*78%*	*81%*	*72%*	*81%*	*8%*	*n.a.*
Total	**441**	**775**	**1 018**	**1 440**	**1 908**	**100%**	**100%**	**1 133**	**3.4%**

* Compound average annual growth rate.

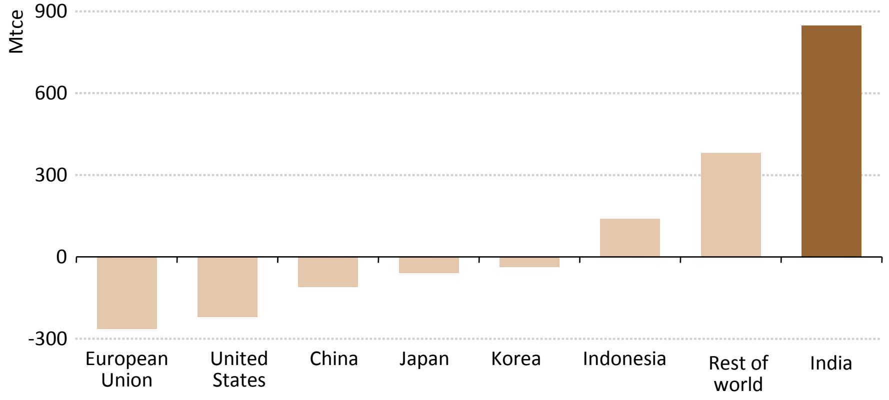
Figure 2.2 ▷ India domestic energy balance, 2013 and 2040 (Mtoe)



* Transformation of fossil fuels (e.g. oil refining) into a form that can be used in the final consuming sectors (excludes blast furnaces and coke ovens). ** Includes fuel consumed in oil and gas production, transformation losses and own use, generation lost or consumed in the process of electricity production and transmission and distribution losses. *** Includes energy demand from blast furnaces and coke ovens, as well as petrochemical feedstock.

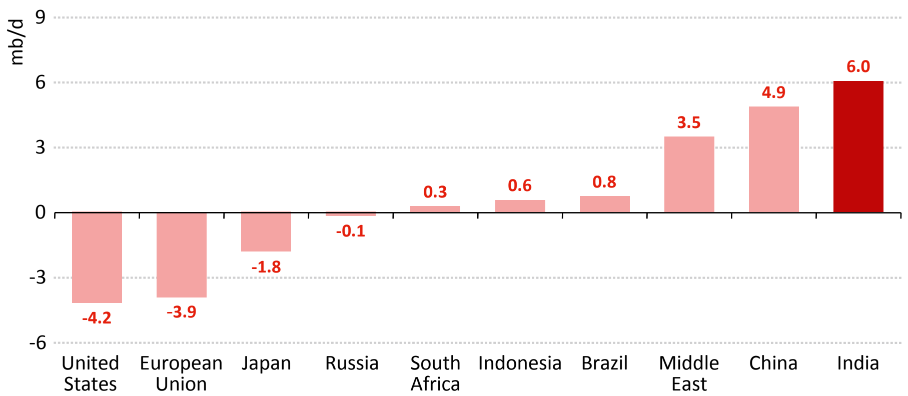
Indian coal consumption of 1 300 million tonnes of coal equivalent (Mtce) in 2040 is 50% more than the combined demand of all OECD countries and second only to China in global terms. The projected increase in coal use is split between power generation (to feed an additional 265 GW of coal-fired plants) and industry (primarily for iron, steel and cement industries). This makes India, by a distance, the largest source of additional global coal demand (Figure 2.3).

Figure 2.3 ▷ **Change in coal demand by selected countries and regions in the New Policies Scenario, 2013-2040**



Demand for oil in India increases by more than the growth in any other country or region in the world to 2040, by 6.0 million barrels per day (mb/d) to reach 9.8 mb/d (Figure 2.4). Transport accounts for 65% of the rise, as 260 million additional passenger cars, 185 million new two- and three-wheelers and nearly 30 million new trucks and vans are added to the vehicle stock. The pattern of transport fuel use remains weighted towards diesel, although gasoline shows a faster rate of growth. The rise in transport fuel demand would be even greater were it not for the introduction of fuel-efficiency standards, allied with policy efforts to promote alternative fuels. Oil – mainly in the form of liquefied petroleum gas (LPG) – is in strong demand also in the residential sector, largely thanks to policies aimed at encouraging a move away from solid biomass for cooking. The trajectory of India's oil use, and the implications for India's oil security and import bills, depend greatly on the way that global oil markets and prices evolve (Box 2.2).

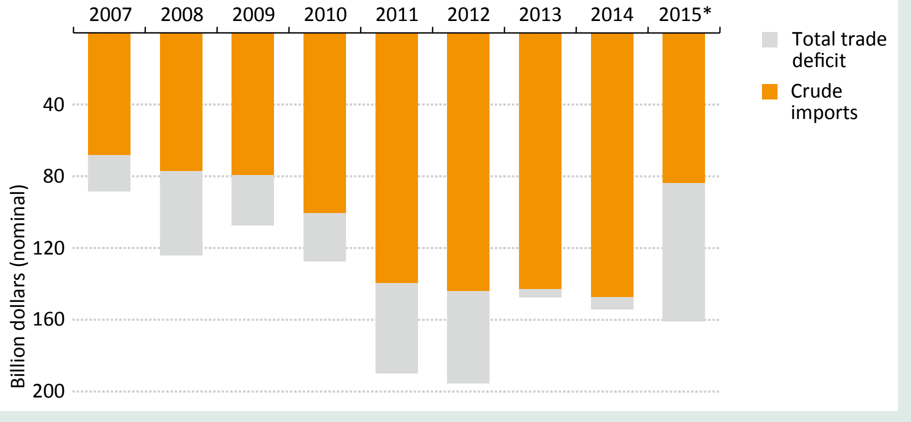
Figure 2.4 ▷ **Change in oil demand by selected countries and regions in the New Policies Scenario, 2014-2040**



Box 2.2 ▷ India in a Low Oil Price Scenario

India is the third-largest importer of crude oil in the world. By value, crude oil accounts for one-third of total imports, averaging around $135 billion a year since 2011 (although offset in small part by net exports of oil products) (Figure 2.5). Fluctuations in the oil price are therefore fundamentally important to the Indian economy. At $60/barrel, India makes annual savings in its import bill of $70 billion compared with the average oil price, above $100/barrel, which prevailed from 2011 until mid-2014. That reduction is equivalent to fourteen-times the government budget allocation to the health sector.

Figure 2.5 ▷ Crude oil imports as a share of the trade deficit



* Estimate.

Sources: Ministry of Petroleum and Natural Gas (2014); IEA analysis.

Lower oil prices can feed back positively to the economy in a number of ways. They reduce household expenditure on energy (around 30% of energy expenditure in India's cities is allocated to gasoline and diesel), freeing up income that stimulates domestic demand, while reducing the country's current account deficit. They alleviate the fiscal burden for oil products that are subsidised, a consideration that has been worth around $3.5 billion in the case of LPG. As well, with fuel accounting for the fourth-largest component of the Indian Consumer Price Index, lower oil prices translate into lower economy-wide inflation.

In the New Policies Scenario, these gains are expected gradually to dissipate: oil prices rise as global demand picks up and supply growth falls back (the latter as cuts in non-OPEC upstream spending eventually feed through into lower output). The rise in price, to $128/barrel in real terms by 2040, takes the edge off India's thirst for oil-based mobility, although demand still increases rapidly. The result is a bill for oil and gas imports that reaches almost $480 billion by 2040, up from $110 billion today.

In the *World Energy Outlook 2015* (IEA, 2015), we also model a Low Oil Price Scenario to examine the implications of a much more protracted period of lower prices. This scenario sees prices in the $50-60/barrel range until the mid-2020s, before they start a slight rise to reach $85/barrel by 2040. This trajectory results primarily from much more favourable assumptions about the availability of low-cost supply, as the main resource-holding countries in the Middle East pursue a policy of increasing their share of the market and output in some key non-OPEC countries (notably US tight oil) proves to be resilient even in a low-price environment.

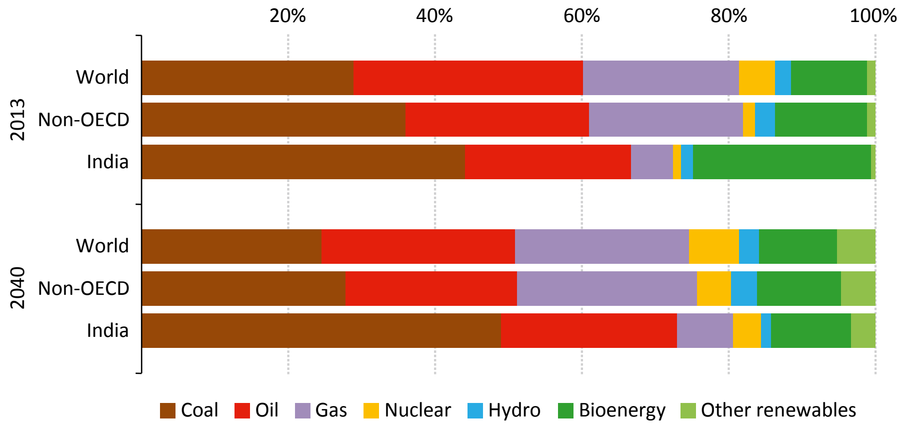
For India, as a major oil consumer, this scenario reduces energy expenditure across the economy, stimulating additional growth. Oil consumption rises more quickly in all sectors, particularly transport, as consumers take advantage of the lower cost of mobility. Coal is slightly cheaper to produce and transport, keeping a lid on electricity prices. The price of India's liquefied natural gas (LNG) imports comes down and stays relatively low, helping gas find a larger foothold in the Indian mix. Average household incomes rise because of a range of direct and indirect energy price effects and the macroeconomic benefits for the Indian economy as a whole. India's total oil and gas import bill in 2040 – even with 6% higher import volumes for oil – is lower by $135 billion (almost 30%) than in the New Policies Scenario. Lower oil prices also help contain the fiscal deficit, as expenditure on subsidies is reduced, making it easier for the government to invest in physical and social infrastructure.

Yet the impacts of this scenario on Indian interests are by no means all positive. Domestic oil and gas production, which is relatively expensive by international standards, is hit hard by lower prices. With many new projects no longer viable, India's oil production is down 10% compared with the New Policies Scenario (see Chapter 3). The combination of higher oil demand (which reaches 10.3 mb/d in 2040) and lower domestic output (0.6 mb/d in 2040) means a very rapid increase in net oil imports. This fosters very strong reliance on supply from the Middle East – the main source of lower cost oil, whose increased production is instrumental in keeping prices down over the long term in the Low Oil Price Scenario – with implications for the measures India needs to take to guarantee security of supply.

Natural gas plays a relatively minor role in the Indian energy mix in the New Policies Scenario, certainly compared with the world and non-OECD averages (Figure 2.6). Gas use is projected to make in-roads in many sectors, from power generation to transport, while retaining an important role as a feedstock for the fertiliser industry. But, despite its versatility and low environmental footprint, compared with coal, its relatively high price does not allow it to displace other forms of energy more rapidly.

Around 36% of India's primary energy supply is used today as an input to power generation, including around 65% of its coal, 31% of its gas, its nuclear and hydro components and the bulk of the contribution coming from other renewable sources, excluding bioenergy.[1] In the New Policies Scenario, electricity consumption grows more quickly than demand for any of the individual fossil fuels; this is also the area in which non-fossil fuel energy has a growing impact. Despite the large expansion in the coal-fired fleet and steady growth also from gas-fired power, more than half of the electricity generation capacity additions anticipated in India over the period to 2040 come from nuclear, hydropower and other renewables, with solar photovoltaics (PV) making the second-largest contribution after coal.

Figure 2.6 ▷ Primary energy mix in India and by selected regions in the New Policies Scenario



Notes: Other renewables includes wind, solar, geothermal and marine. Non-OECD excludes India.

End-use sectors

Consumption across India's end-use sectors – buildings, industry, transport and agriculture – increases by around 3.3% per year on average to 2040, more than doubling to reach 1 275 Mtoe, by which time it overtakes the level of final consumption in the European Union today. Apart from the sizeable increase in demand, there is a material reconfiguration in the way energy is consumed by the main sectors (Table 2.2). Strong growth in the transport sector and in industry, underpinned by the growing economy, increases the share of both in overall consumption and consolidates the position of industry as the largest end-user of energy in the Indian economy. The main fuels contributing to this end-use demand growth (Figure 2.7) are coal (in industry), oil (in transport), and electricity (in buildings, industry and agriculture). The amount of bioenergy used in Indian end-use sectors remains stable in absolute terms, which translates into a falling share of the total.

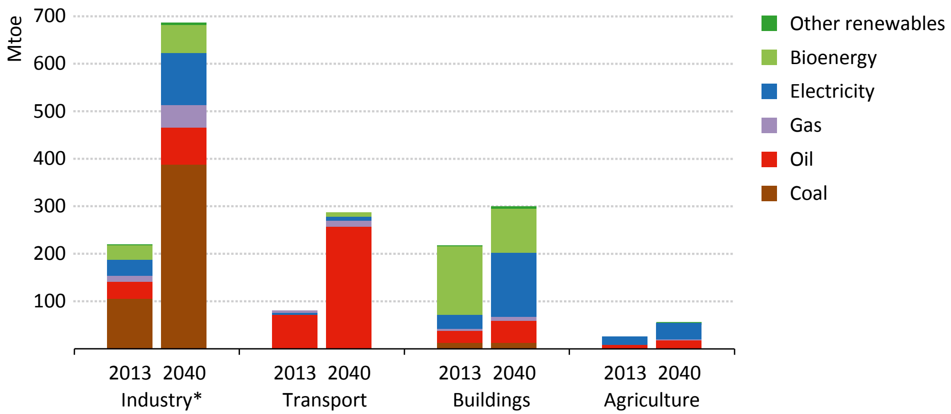
1. The share of primary energy going into the electricity sector does not provide a good indication of the eventual power generation mix, because of the different conversion efficiencies of various fuels. As Figure 2.2 shows, a great deal of energy is lost in the transformation from primary energy to electrical energy; most of this is from fossil fuels, whereas in the IEA methodology, many renewable energy technologies, including hydropower, wind and solar, have an assumed conversion efficiency of 100%, i.e. zero conversion losses.

Table 2.2 ▷ Final energy consumption by sector in India in the New Policies Scenario (Mtoe)

	2000	2013	2020	2030	2040	Shares 2013	Shares 2040	2013-2040 Change	2013-2040 CAAGR*
Industry	83	185	263	417	572	35%	45%	388	4.3%
Transport	32	75	108	176	280	14%	22%	205	5.0%
Road	28	68	100	165	264	13%	21%	196	5.1%
Buildings	158	214	242	274	299	41%	23%	85	1.2%
Agriculture	15	24	31	43	51	5%	4%	27	2.9%
Non-energy use**	27	29	40	58	72	6%	6%	43	3.4%
Total	**315**	**527**	**686**	**968**	**1 275**	**100%**	**100%**	**748**	**3.3%**
*Industry, incl. transformation****	111	217	317	507	691	n.a.	n.a.	474	4.4%

* Compound average annual growth rate. ** Includes petrochemical feedstocks and other non-energy uses (mainly lubricants and bitumen). *** Includes energy demand from blast furnaces and coke ovens (not part of final energy consumption) and petrochemical feedstocks.

Figure 2.7 ▷ Energy demand by fuel in selected end-use sectors in India in the New Policies Scenario



* Includes energy demand from blast furnaces, coke ovens and petrochemical feedstocks.

Buildings

Energy use in the buildings sector (both the residential and services sectors[2]) in India is projected to change dramatically over the coming decades under the influence of population growth, the trend towards urbanisation, growth in access to modern energy and the impact of rising incomes on the ownership of appliances. From a situation in 2013 when almost 65% of the 214 Mtoe consumed in the buildings sector consisted of solid biomass,

2. The services sector includes, among others, public buildings, offices, shops, hotels and restaurants.

Box 2.3 ▷ What India builds is crucial to the future of energy use

Some three-quarters of the anticipated building stock in India in 2040 has yet to be constructed; a consideration that has enormous implications for our energy *Outlook* and for policy-makers. Strong growth in construction pushes up energy consumption in order to produce the steel, cement, aluminium and other materials required. But it also creates an opportunity for India to impose more stringent efficiency standards on the buildings sector, with the focus on keeping demand for cooling in check, as part of its drive for efficient "smart" cities. The alternative is to risk locking in inefficient capital stock for the long term.

With this in mind, in 2007 India launched an Energy Conservation Building Code (ECBC) that sets minimum energy standards for new commercial buildings (those with energy requirements above a certain threshold). The code is voluntary until made mandatory by individual state governments, who can also amend it to suit local climatic conditions; but it has already been adopted for all central government buildings and in a majority of states, and the aim is to extend coverage across the country by 2017.[3] The Bureau of Energy Efficiency has released guidelines for energy-efficient multi-storey residential buildings, although there is little in the way of mandatory regulation for this sector.

In June 2015, India officially launched the Smart Cities Mission, the centrepiece of which is the aim to develop 100 smart cities across India. This is an opportunity to improve energy, water and waste management, for example through the installation of smart meters or by using waste to produce energy. Other objectives of the mission are to reduce the energy demand of existing buildings, via retrofits, and to enhance the efficiency of new construction more generally; positive examples of these approaches include the redevelopment of East Kidwai Nager in Delhi and the Gujarat International Finance Tec-City (GIFT) project in Gujarat. One important feature of the smart cities initiative is that it incorporates the objective of providing housing opportunities to all.

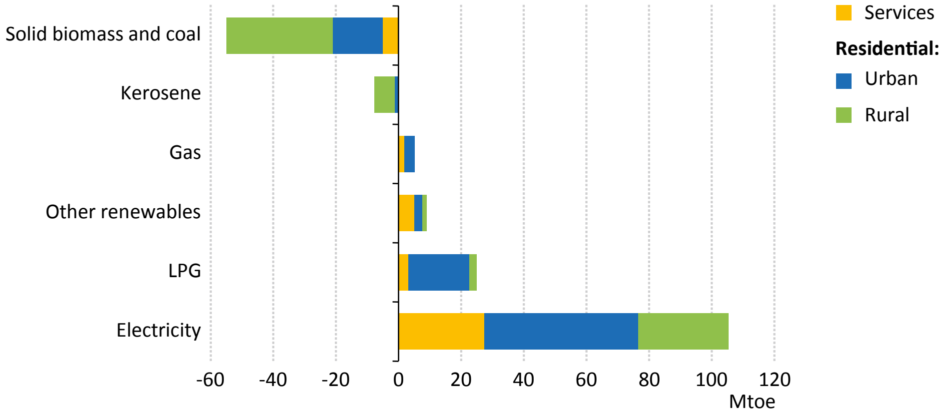
It will take time to extend the scope of the relevant measures in order to make residential buildings more efficient, in particular, to build the capacity to ensure compliance with the energy elements of building codes. But the prize, in terms of reduced energy consumption, is significant. We estimate that if standards equivalent to the ECBC were made mandatory for all new buildings (both commercial and residential) and existing voluntary appliance standards became compulsory by 2030, energy consumption in buildings would be 50 Mtoe, or 17%, lower than in the New Policies Scenario by 2040.

3. Other initiatives, such as the Green Rating for Integrated Habitat Assessment (GRIHA) programme launched by The Energy Resources Institute (TERI) and the Bureau of Energy Efficiency's Star Rating scheme that targets existing commercial buildings have also gained traction, but remain voluntary.

by 2040 more than 60% of the 299 Mtoe used in the sector is either electricity (45%) or oil (16%). This projection is underpinned by growth in India's towns and cities, which accommodate an estimated additional 315 million people over the *Outlook* period (ten-times the additional number of people in rural areas). Urbanisation helps to improve access to modern fuels, such as electricity and LPG, but it can also – if not well planned – entrench inefficient patterns of energy use that can be very difficult to dislodge (Box 2.3).

The two components of energy use in the buildings sector (the residential and services sectors) have very different patterns of consumption. In India today the residential sector relies mainly on solid biomass, with oil a distant second (LPG for cooking, kerosene for cooking and lighting) followed by electricity. The services sector, which tends to be concentrated in urban areas, is already largely dependent on electricity. Future increases in energy consumption in the services sector – including a jump in demand for space cooling in buildings – are projected to be predominantly based on electricity (with India's building codes and minimum energy performance standards serving to moderate the rate of growth). The projected shifts in demand in the residential sector, by contrast, are much larger and more varied (Figure 2.8).

Figure 2.8 ▷ Changes in energy consumption in the buildings sector in India in the New Policies Scenario, 2013-2040



Notes: Other renewables in this figure includes also modern uses of biomass (biogas and pellets). Solid biomass covers fuelwood, charcoal, dung and agricultural residues.

Today more than 70% of energy used in households in India is for cooking (whereas cooking constitutes less than 5% of residential energy demand in OECD countries). Two-thirds of the Indian population rely on solid biomass as their cooking fuel (Government of India, 2012), due to the lack of options that are similarly available and affordable; the low efficiency of this cooking method, compared with LPG or electric stoves, pushes up the share of solid biomass in cooking energy demand to more than 85%. Changes in the fuels used for cooking account for some of the main changes in residential energy demand over the period to 2040, alongside fuel switching for lighting purposes from kerosene (mostly in rural areas) to electricity, and rising electricity consumption to meet large increases in demand for cooling equipment and appliances. There is not much call for space heating in India, as daytime temperatures in its most populated areas are on average higher than 20 °C.[4] Water heating in large parts of India is largely a seasonal need.[5]

From the starting point that we describe in Chapter 1, the residential energy outlook in the New Policies Scenario is marked by a series of transitions, away from solid biomass and from kerosene to LPG and from unreliable or unavailable electricity to round-the-clock, reliable supply. These shifts happen at different speeds in different parts of the country and are set against a broader transition from a predominantly rural to an increasingly urban society. The net result is a transformation of the nature of residential energy consumption that includes universal electricity access, though only a partial achievement of complete access to clean cooking facilities (Box 2.4)

Box 2.4 ▷ Transition towards cleaner cooking facilities in India

Today around two-thirds of the Indian population rely on solid fuels as the primary fuel for cooking. This share varies widely between urban and rural households, with only a quarter of urban households using solid biomass for cooking (many moving to use LPG), compared with more than 85% of households in rural areas.[6] The adverse consequences fall predominantly on women and children, who suffer the worst health effects of the smoky indoor environment and also spend more time collecting firewood: one estimate says that Indian women spend, on average, 30 hours per month collecting cooking fuel (Practical Action, 2015).

In most rural areas in India, it is a challenge to displace solid biomass as the dominant fuel for cooking. Biomass scarcity is not yet at the level at which it forces a transition to other fuels and although LPG is promoted as an alternative and each household is entitled to buy 12 LPG cylinders per year and to receive the related subsidies as direct payments to their bank account (if they have subscribed to the PaHal scheme), distribution networks for LPG are limited in rural areas and, even with the subsidy,

4. Space heating is only prevalent in parts of northern India, typically the more mountainous or hilly regions, for three or four months per year. These areas typically rely mainly on solid biomass both for cooking and for space heating. At lower altitudes, heating is required for around one month per year.

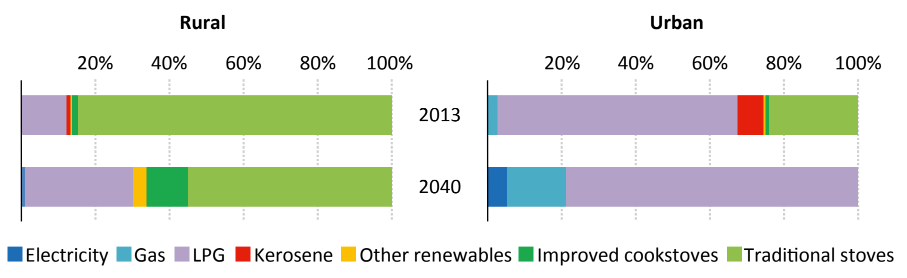
5. Water heating systems are used for two to four months of the year (depending on the region). There is usually no centralised system installed in residential buildings. Electric water heaters sized for household needs are the most popular option, where affordable: otherwise most households rely on the stoves used for cooking to heat water. Use of solar water heaters is negligible today but is set to increase, both for residential and commercial buildings.

6. Trends indicated in the most recent census in 2011 and confirmed in more recent energy data, show that the shift from fuelwood and kerosene to LPG as a cooking fuel is concentrated in urban areas. But even as LPG use is increasing, households often rely on more than one fuel for cooking, a phenomenon known as fuel stacking: when oil prices fluctuate or LPG delivery is not available, households can choose to go back to the use of cheaper (or free) solid biomass.

the cost can deter the poorest households. Biogas seems a promising avenue for India (based on ample agricultural residues) and there have been long-standing efforts to promote it, but less than 1% of households use biogas as their primary cooking fuel.

Government measures are accelerating the transition to alternative fuels but, in our judgement, the scale of the challenge means that solid biomass is unlikely to be entirely displaced by 2040. In the New Policies Scenario, the number of people without access to clean cooking facilities is projected to decline from around 840 million today to 480 million in 2040, all living in rural areas. Urban households all switch from solid biomass by 2040 (and from kerosene as well) as a cooking fuel, using instead, LPG and, in some instances, piped natural gas and electricity (Figure 2.9).[7]

Figure 2.9 ▷ Primary fuel/technology used by households for cooking in the New Policies Scenario



Note: Other renewables in this figure is mainly solar cookers and biogas stoves.

If solid biomass is here to stay as a cooking fuel, one way of reducing the health impacts is to encourage a switch to more efficient biomass cookstoves. The National Programme on Improved Chulhas distributed approximately 35 million improved biomass stoves from the 1980s until the early 2000s, but these did not catch on as hoped (many users tended to revert back to the traditional open fire over time) and there is some evidence that the subsidised supply hindered the emergence of a local commercial market for improved cookstoves (Shrimali et al., 2011). Incorporating the lessons learned, a new National Biomass Cookstove Initiative was launched in 2009.

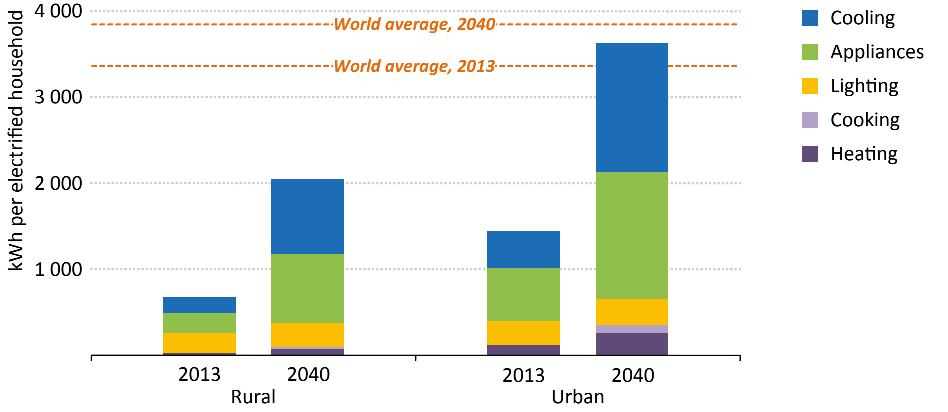
As incomes rise and electricity supply becomes more reliable, India is set to see a rapid increase in household electricity consumption, via increased purchases of appliances and air conditioners, although the rate of change again varies substantially between urban and rural households (Figure 2.10). The increase in demand for cooling is particularly striking: at present, the predominant appliance used for space cooling is an evaporative air cooler, which consumes twice as much electricity as a fan. However, as incomes rise,

7. Gail Gas Limited reports to have already connected 650 000 households in Uttar Pradesh, Madhya Pradesh and other states, while Indraprastha Gas Limited supplies almost 600 000 households in and around Delhi.

more people are in a position to afford air conditioners, which can consume five-times as much electricity as an evaporative air cooler. The market for air conditioners is already growing rapidly: sales of around 1 million units in 2003-2004 rose to more than 3 million units in 2010-2011 (Phadke, Abhyankar and Shahh, 2014) and very strong further growth is expected, with one estimate putting annual sales as high as 50 million units by 2050 (Chaturvedi and Sharma, 2015).

In order to ease the growth in electricity consumption in the buildings sector (but also in industry and agriculture), the Bureau of Energy Efficiency set up a programme of standards and labelling for appliances in 2006. Only 4 out of the 21 standards are currently mandatory, but more are expected to become mandatory in the coming years and there are plans to add standards for other appliances. The programme focuses on the most widely used appliances (specific types of refrigerators and air conditioners are already covered by the mandatory scheme), with voluntary labels initially encouraging consumers to choose more efficient appliances and then a switch to mandatory standards being made once there is sufficient public acceptance. By the end of 2015, the standards for electric water heaters, direct-cool refrigerators and colour televisions are expected to become mandatory. However, experience shows that the effect on consumption is offset somewhat by an increase in the size and power of the appliances on the market: the average size of refrigerators 15 years ago was around 165 litres, it is now 265 litres. Keeping future electricity consumption growth in the buildings sector in check will require a steady tightening of appliance standards.

Figure 2.10 ▷ Annual electricity consumption per rural and urban electrified household in India, 2013 and 2040



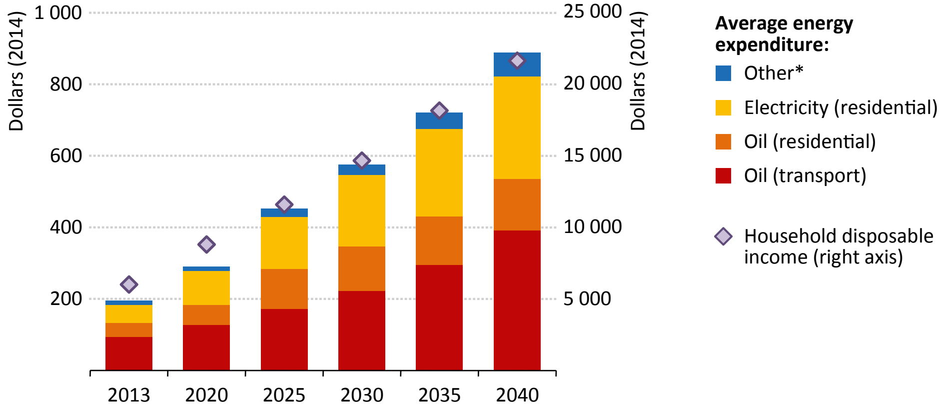
Note: kWh = kilowatt-hours.

Affordability

Energy consumption patterns, including how much is used and in what form, are heavily influenced by the level of disposable income available to households in India (see Chapter 1). Over the projection period, average household disposable income in

India is projected to rise to almost four-times its current level, reaching almost $22 000 (in 2014 dollars), while household spending on energy increases from just under $200 per year to almost $900 per year, meaning that energy expenditure as a share of total disposable income increases from 3% in 2013 to 4% in 2040 (Figure 2.11). This increase in expenditure is driven by oil consumption for road transport (reflecting the increasing demand for mobility) and consumption of electricity (as increasing incomes push up appliance ownership and use). Expenditure patterns are naturally contingent on the way that end-user prices evolve – in particular whether the scale of tariff increases for electricity is restrained by an efficient expansion of power generation and a reduction in high network losses. Keeping these energy costs under control (while still allowing for overall cost recovery across the system as a whole) has important implications for welfare as well as the wider economy, as any rise in energy expenditure comes at the expense of consumer spending on other goods and services (or on amounts that are saved and therefore potentially available to support productive investment in other parts of the economy). At an aggregate level, each $1 increase in annual household energy expenditure absorbs $400 million that could be spent, saved or invested in other parts of the economy.

Figure 2.11 ▷ Average energy expenditure by fuel and household disposable income, 2013-2040



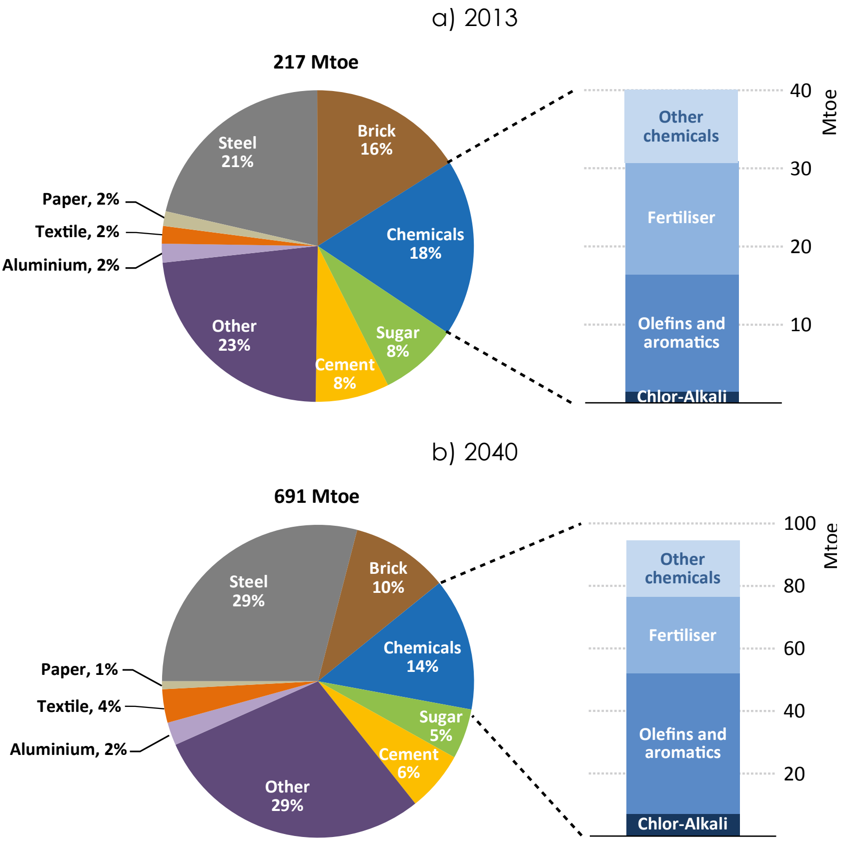
* Includes coal and natural gas used in the residential sector, and biofuels, electricity and natural gas used in transport.

Industry

Energy demand in the industry sector is projected to increase rapidly, by 4.4% annually to 2040, so as to account for more than 50% of final consumption by 2040, up from 40% today. India's huge infrastructure needs over the next decades drive the demand for energy-intensive materials, for which India becomes an important manufacturing hub. Traditional building materials, such as clay bricks, are increasingly being replaced by steel and cement, which explains the increased share of steel in industrial energy consumption

(Figure 2.12). In addition, industries ranging from chemicals, textiles and food to transport equipment are increasing their production quickly to satisfy the needs of a larger and more prosperous society.

Figure 2.12 ▹ Estimated current and projected industrial energy consumption by sector in India in the New Policies Scenario



Coal is currently the dominant source of energy for industry, accounting for almost 50% of industrial energy use. With increasing demand from different branches of industry, including steel, bricks and cement, bolstered by the consideration that coal is less expensive compared with alternative fuels, the share of coal grows to 56% in 2040. Natural gas, oil and biomass consumption grow in absolute terms, but their shares of total industrial demand decline. Gas consumption is held back by the subdued growth in domestic production, relatively high import prices and limited distribution infrastructure. National policy encourages a move away from the traditional use of biomass, while oil products represent an increasingly costly way of providing heat to industry.

The structure and patterns of energy consumption in the various industrial branches in India are very different: some energy-intensive industries, including chemicals, cement, aluminium and, to some extent, steel, are dominated by large enterprises; others, particularly the brick industry, consist of thousands of small and medium enterprises (SMEs). The latter, with generally poor energy performance, account in total for about 45% of manufacturing output (SME Chamber of India, 2015). The energy efficiency policies of the Indian government focus on the large consumers, for whom participation in an innovative market-based trading scheme for energy efficiency certificates is mandatory (Box 2.5).

The steel sub-sector is the largest industrial energy user in India and is also the source of the largest projected increase in industrial energy use over the period to 2040, from the current 46 Mtoe to around 200 Mtoe (supporting output that increases by more than five-times). India is already the fourth-largest steel producer in the world after China, Japan and the United States, but it overtakes both the United States and Japan before 2020. With an anticipated decline in domestic demand, China is expected to seek export markets in order to make good use of its large existing steel production capacity; however, imports into India are projected to reduce Indian domestic production growth only to a limited extent. Currently, 20% of inputs to the steel industry consist of coal-based sponge iron (or direct reduced iron [DRI]), with the rest being traditional pig iron from blast furnaces and steel scrap. India is the only country in the world that uses coal instead of natural gas for large-scale DRI production. The energy consumption of coal-based DRI can be up to twice as high as that of gas-based DRI (IEA, 2007). India has three major gas-based DRI producers, which ran at an utilisation rate of below 30% in 2013, due to low availability of domestic natural gas (JPC, 2014). The high production of coal-based sponge iron is a consequence of the facts that DRI facilities are easy to build, as in general they are small and less capital-intensive, that India does not have access to low-cost natural gas and that domestic coking coal, necessary for traditional pig iron production, is of relatively low quality, with high ash content.

The steel industry in India consists of relatively efficient large, private sector steel plants, alongside less efficient public steel plants and a significant number of mini blast furnaces that cannot reach the energy efficiency levels of larger plants due to their small scale. Roughly a third of India's steel is produced in electric arc furnaces and a similar proportion in small-scale induction furnaces (JPC, 2014), which use electricity as an energy input and where the scope for energy efficiency gains is limited. In the future, it is anticipated that the steel sector in India will become less reliant on DRI, turning more towards the traditional blast furnace route for steel-making and so depending less on electricity supply. This shift, combined with increasing energy efficiency gains, (particularly in blast furnaces, steel finishing and exploiting the waste heat potential in DRI production), and a modestly higher share of scrap metal contribute to the projected decrease in energy intensity. The shift from DRI relying on domestic non-coking coal production towards primary steel-making means that India will become more reliant on more expensive imported coking coal for its blast furnaces.

Box 2.5 ▷ India's policies on energy efficiency in industry

Under the Energy Conservation Act, a market-based trading programme for efficiency certificates, called the Perform, Achieve and Trade (PAT) scheme, was introduced in 2012. It specifies energy saving targets for 478 facilities with an energy consumption of more than 30 thousand tonnes of oil equivalent (ktoe) (lower for some industries) in the aluminium, cement, chlor-alkali, fertiliser, steel, paper and textiles industries. The scheme targets energy savings of 6.7 Mtoe (or 4%) at the end of the first cycle in March 2015 (CDKN, 2013). In mid-2015, the Bureau of Energy Efficiency evaluated the energy savings to determine which companies are to receive efficiency savings certificates for over achieving their target and which have to buy certificates in the market or face a penalty as a result of not meeting their target. The second cycle of the PAT scheme starts in April 2016 and includes more companies by lowering the consumption threshold and adding three additional industries: railways, electricity distribution companies and refineries.

Implementing energy efficiency policies for SMEs is difficult due to their diverse nature, lower awareness, the perceived risk of some efficiency technologies, lack of capital and high transaction costs. The Bureau of Energy Efficiency has targeted industrial clusters, where SMEs have based themselves around locally available resources. In these clusters, energy use assessments, efficiency manuals and capacity building are provided to particularly energy-intensive SMEs, such as the food, brick or textile companies, with the objective of saving 1.8 Mtoe in 2016/2017. Financial assistance and low-interest loans are available for selected energy efficiency measures and management systems in SMEs (partially funded by development banks).

The brick industry in India is the second-largest in the world (after China) and also the second-largest energy consumer after iron and steel. Its structure is very different from that encountered in OECD countries, which rely on automated tunnel kilns for the production of hollow or perforated bricks. Brick production in India is very labour-intensive (often in very poor working conditions), it is a large consumer of biomass and production is spread out over more than 100 000 small plants (Government of India, GEF, UNDP, 2012). India's brick industry is very seasonal and limited to about six months: green bricks are formed from mid-October to end-December and are subsequently dried in the open. They are fired when the weather gets warmer from mid-March until June. Given its small-scale character, relying on traditional production methods, the brick industry has significant potential for higher energy efficiency. Approximately 70% of the estimated 250 billion bricks produced per year are made in fixed chimney bull trench kilns, a relatively inefficient production method that is also a major source of local air pollution (Lalchandani and Maithel, 2013). More modern techniques, such as zig-zag firing, can reduce specific energy consumption from up to 1.4 megajoules per kilogram (MJ/kg) to around 0.8-1.1 MJ/kg, i.e. an energy saving of more than 20% (Maithel, 2013). While it is projected that energy intensity in the Indian brick industry will decline by around 30% by 2040, through a combination of energy efficiency and a shift towards the manufacture of hollow and perforated bricks, realising these efficiency gains will be difficult because of a lack of awareness, the high payback periods associated with energy efficiency projects and a lack of appropriate financing means by local banks. These hurdles are gradually overcome in our projections through various efficiency policies, including capacity building and financial assistance.

The domestic fertiliser industry is a major energy consumer as well as a pillar of India's efforts to ensure food security. Of the three broad categories of nutrients available to India's more than 100 million farmers, most of the phosphorus- and potassium-based fertilisers are imported, while about three-quarters of the nitrogen-based urea fertilisers are produced at home (Department of Fertilizers, 2015). In 2013, the fertiliser industry consumed about 13.5 Mtoe (15.8 billion cubic metres) of natural gas for use as feedstock. Though it is no longer first in line, the fertiliser industry is one of the sectors with priority access to domestically produced gas (which is available at a regulated price). Imported LNG met almost one-third of the fertiliser industry requirements in 2013.

Subsidies provided to the industry since the 1970s have made fertilisers more available to farmers, but come at a significant cost (similar to electricity subsidies provided to farmers, see agriculture section). The prices for all fertilisers are now unregulated with the exception of urea, where the maximum retail price is currently fixed at Indian rupees (INR) 5 360 ($87) per tonne[8], significantly below world market prices (around $300/tonne in 2014) (Department of Fertilizers, 2015). Subsidies for fertiliser producers make up a substantial portion of all subsidies in India (26% in 2012), totalling INR 660 billion ($12 billion) in 2012, 0.7% of Indian GDP (Ministry of Petroleum and Natural Gas, 2014). A large part of this subsidy is spent on the domestic production of urea, with the rest to import urea and the production of other, more complex fertilisers.

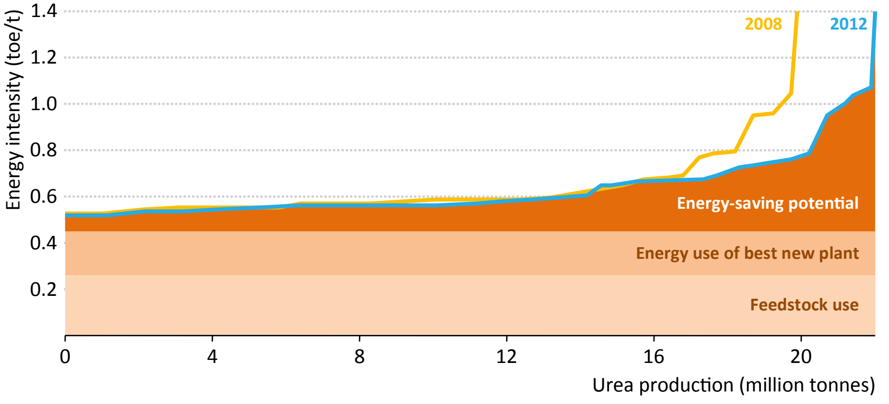
The subsidies have led to over-consumption of urea, relative to other fertilisers. The ideal ratio of nitrogen (N), phosphorus (P) and potassium (K) in fertiliser use is around 4:2:1, but, for example in the case of Rajasthan, the ratio reached 45:17:1 in 2012, damaging the chemistry of the soil (Gulati and Banerjee, 2015). Subsidies also discouraged producers from paying close attention to their costs, although changes to the subsidy rules and the inclusion of the fertiliser sector in the PAT scheme have addressed these inefficiencies. The intention now is to shift the subsidy scheme away from producers, instead concentrating on compensating farmers directly.

The energy intensity of urea production has decreased significantly from 0.84 toe/tonne urea in 1990 (Nand and Goswami, 2008) to around 0.64 toe/tonne urea in 2013. Future energy intensity reductions become more limited as 0.26 toe/tonne of energy is needed as a feedstock, and best practice energy use for urea plants is currently around 0.19 toe/tonne

8. The maximum retail price is roughly equivalent to the entire non-energy related production cost component in the production of urea. Consequently, in order to break-even at current regulated prices, natural gas effectively needs to be available at zero cost. In other words, the entire $12 billion of fertiliser subsidies can be seen as indirect subsidies for the use of natural gas.

urea (Figure 2.13). In our projections, the energy intensity of urea production decreases further to 0.55 toe/tonne urea by 2040 (a further 15% improvement compared with today), representing a reduction of 4 Mtoe (4.8 bcm) in the amount of natural gas required compared to a situation if there were no future efficiency gains.

Figure 2.13 ▷ Energy intensity of urea production in India



Sources: Department of Fertilizers (2014); IEA analysis.

Other large industrial consumers of energy include the cement, petrochemicals, paper and aluminium industries. The cement industry is projected to almost treble its energy demand by 2040, as it strives to meet the demand related to heavy infrastructure spending and ongoing urbanisation. The cement industry in India is already one of the most energy-efficient in the world, with relatively large production units and the use of modern technologies; it uses a relatively high share of fly ash and blast furnace slag as a substitute for energy-intensive clinker production. In the future, the clinker-to-cement ratio declines from the current 0.74 to 0.62 in 2040 (reducing the energy intensity of cement production by 13%) driven by a higher availability of blast furnace slag from the steel industry.

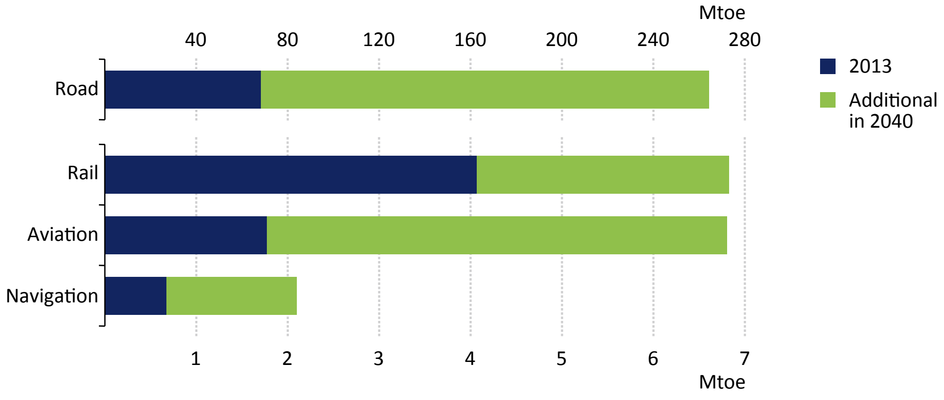
India has very low per-capita consumption of petrochemical products at present, but demand is increasing from the textile, car manufacturing and food packaging sub-sectors, among others, and will provide a boost for domestic petrochemical manufacturing. Production of ethylene, the most important basic petrochemical, is expected to increase from 3 million tonnes (Mt) in 2013 to 13 Mt in 2040. For feedstocks, the petrochemicals industry in India relies heavily on domestic naphtha from its important refining industry but has recently also looked to import ethane from the United States.

Aluminium production in India currently consumes around 4 Mtoe, a figure projected to increase to 16 Mtoe in 2040. Primary aluminium production, which is very electricity-intensive, increases four-fold by 2040. Around 80% of India's aluminium sector is already using the world's best available smelting technology and the remaining 20% is expected to be upgraded by 2040. However, paper production in India is significantly more energy-intensive than in other parts of the world, because its mills are currently small: the average size is less than 15 000 tonnes per year, while large-scale modern plants produce at least twenty-times as much. As the structure of the Indian paper industry is not expected to change significantly and it relies for more than one-fifth of pulp production on agro-based feedstocks (as opposed to more common wood-based pulp), future energy efficiency gains are expected to moderate (TERI, 2015).

Transport

Energy use in India's transport sector, at 75 Mtoe in 2013, accounted for 14% of final energy consumption – a much lower share than in many other countries. With a growth rate averaging 6.8% per year since 2000, it has become the fastest-growing of all the end-use sectors, with around 90% of the increase coming from oil use in road transport. All the indicators point to further significant increases in demand: passenger vehicle ownership, at less than 20 vehicles per 1 000 inhabitants, is much lower than the world average; the use of energy per capita for transportation purposes, at 0.06 toe, is one-sixth of the world average; and the number of flights, at 0.07 trips per capita, is well below that of other emerging economies (Airbus, 2015). In the New Policies Scenario, growth in energy demand from transport continues to outpace growth in all other sectors, and transport fuel demand reaches 280 Mtoe in 2040, dominated by road transport (Figure 2.14).

Figure 2.14 ▷ Transport fuel demand by sector in India in the New Policies Scenario

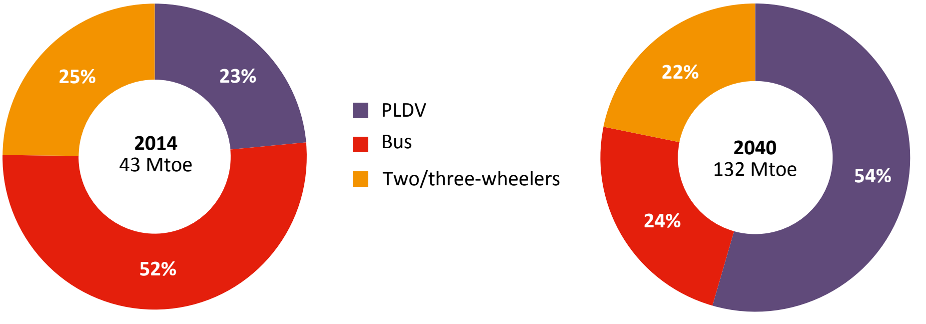


Note: Aviation includes fuel use for domestic travel only.

India's transport sector is distinctive in that it was long dominated by mass transport by rail, first introduced to India in 1853, not long after Western Europe and well before Japan (1872) and China (1876). By the 1950s, when travel demand started increasingly to be satisfied by road transport in many parts of the world, roads carried only 15% of India's passenger movements and 14% of freight (TERI, 2015). Today, however, the picture is markedly different. Transport in India is now heavily dominated by road transport, which accounts for 86% of passenger and almost two-thirds of freight movements. Consequently, road transport fuel demand has grown rapidly to 68 Mtoe in 2013, around 60% of which is used for passenger transport.

Passenger cars still play a relatively minor role in India's overall transport system, partly because much individual travel is made by collective modes of road transport (i.e. buses) and partly because of the high level of use of two- and three-wheelers. In our projections this changes, with the share of passenger cars increasing sharply by 2040, by which time they account for 54% of road fuel demand for personal transport, as car ownership rises to a nationwide 175 vehicles per 1 000 inhabitants (Figure 2.15). This shift in modes of transport is in line with the historical development trend in many other countries.

Figure 2.15 ▷ Road fuel demand for personal transport by type in India in the New Policies Scenario, 2014 and 2040



Note: PLDV = passenger light-duty vehicles.

The growth in fuel demand is partially moderated by the recently adopted fuel-economy standards, which mandate an average fuel consumption per new vehicle of 4.8 litres per 100 kilometres (l/100km) in 2022/23 (from around 6.0 l/100 km today). In the New Policies Scenario, we assume average fuel consumption per new vehicle drops further to 4.3 l/100km in 2040. Freight activity, which grows at an annual average rate of 7.5% to 2040, in line with the value added by the industrial sector in our projections, remains an important component of energy demand in road transport, contributing more than half of the total energy demand growth to 2040. Road freight is a very fragmented but highly competitive market with a large number of small commercial operators. The Indian government is at an early stage of developing fuel-economy standards for heavy-duty vehicles, a measure which has significant potential to curb demand growth.

Much will depend on whether India succeeds in slowing the trend towards individual vehicles, particularly in cities, through the provision of effective public transport (Box 2.6). It will be a huge challenge to build the necessary infrastructure, particularly in those of India's cities that are already characterised by urban sprawl and rapid, often informal, developments at their periphery. Even with effective development of public transport, the anticipated growth of the passenger and commercial vehicle fleet is set to amplify some already pressing problems in road transport. Road safety is among the primary concerns. With around 140 000 people killed in road accidents in 2014, i.e. one person killed every four minutes, India's road accident fatality rate is among the highest in the world. The road transport sector (particularly diesel trucks) is also a major contributor to India's worsening urban air quality (see last section of this chapter).

Box 2.6 ▷ Smart cities – moving mobility back in time?

Rapid social and economic development in India, with a burgeoning middle class and strong economic growth, will have significant impacts on all aspects of people's lifestyles, including personal mobility. India has a long tradition of mass transport by train and bus. These are typically significantly more energy-efficient modes of transport than individual cars. But, following the same patterns of development as elsewhere, the Indian population – in particular in urban areas – increasingly uses personal vehicles to satisfy demand for mobility, amplifying problems such as congestion, accidents and air pollution.

One of the most difficult challenges facing India's drive for smart, well-connected cities is to reverse – or at least moderate – such trends. Attempts are being made, such as through the development of Delhi's metro rail system (following earlier systems in Kolkata and Chennai), an example that is being considered by the authorities in many of India's other large cities such as Lucknow, the capital city of Uttar Pradesh. Another option is the development of systems for rapid transit by bus. Such systems have been implemented in eight Indian cities and accommodated more than 400 000 passengers per day along bus corridors of a combined length of almost 170 km. Some of these, as in Ahmedabad, have proved successful, although the experience of other cities shows that the development of these projects is far from easy. In Delhi, frustrated vehicle owners violated the rules by using the bus lanes and difficulties were experienced in accessing some of the bus platforms.

Energy efficiency policies for urban transport can be grouped into three broad categories: those that allow travel to be "avoided"; those that "shift" travel to more efficient modes; and those that "improve" the efficiency of vehicle and fuel technologies. All of these areas need to be tackled in order to make cities in India smarter in terms of mobility. Good city planning can help to slow transport growth and there may also be opportunities to avoid travel through tele-working (or virtual mobility). Shifting travel modes will require early co-ordination between urban and traffic planners, in particular where the development of a public metro system is envisaged, to ensure dedicated spaces for pedestrians and public transit networks. Policy in India is already moving on several of these points, with fuel-efficiency standards for passenger vehicles, the increasing build-up of metro systems and the Smart Cities Mission.

The quality and availability of roads is another potential constraint: although India has the second-largest road network in the world (after the United States), only about half of the roads are paved. Despite efforts to develop a national highway network (and to shift freight back to railways with the development of dedicated freight corridors), inadequate road infrastructure could remain an important bottleneck in a fast expanding economy: while trucks in most OECD countries easily travel 400-500 km per day, it has been estimated that even new heavy commercial vehicles in India are able to achieve only around 270 km per day, due to the poor quality of roads, heavy traffic, toll stations and multiple checkpoints (mostly at state borders). Older vehicles, which represent more than half of the commercial fleet in India, travel on average only around 130 km per day. In the New Policies Scenario, we assume these problems are moderated, to some extent, but the average annual mileage per heavy truck, at 210 km per day in 2040, still remains below the level of other countries.

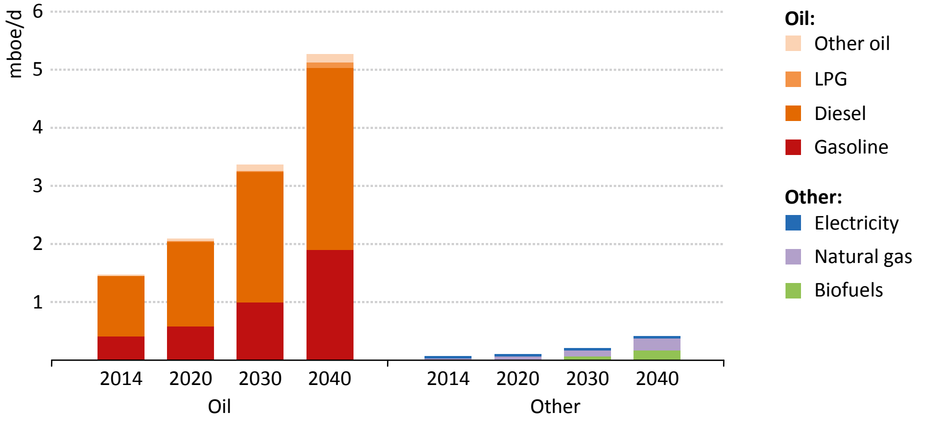
Energy use in other transport sectors remains low in the New Policies Scenario. Domestic aviation, rail and navigation combined contribute only 4% to total energy demand growth in transport, even though they continue to grow at a rapid pace. Aviation and navigation are the fastest growing among these modes, with fuel use for domestic air travel and domestic shipping increasing at an average annual rate of more than 4% until 2040 in the New Policies Scenario. The aviation industry in India has been growing particularly rapidly recently, with double-digit rates of passenger growth handled at the 125 airports managed by the Airports Authority of India. Matching India's increased global connectivity, domestic travel has been spurred by a process of liberalisation that has seen a proliferation of low-cost airlines like IndiGo, SpiceJet and GoAir enter the market. No specific policies in India are directed at reducing aviation fuel demand, but global targets for reducing aviation fuel consumption adopted through the International Civil Aviation Organization, could dampen further demand growth in India.

The railway sector in India has lost its dominance in passenger and freight transport over the past decades, even though the number of passenger-kilometres travelled in India by train, at almost 1.2 trillion, is still the highest in the world. Rail transport fuel use is still heavily dominated by diesel, but electrification efforts continue and the idea of building high-speed tracks between major Indian cities is also gaining ground. To date, 38% of the total railway network in India has been electrified. The further expansion of electrification in the New Policies Scenario increases the share of electricity in total rail fuel use from 33% today to 37% in 2040, with overall rail transport fuel demand increasing by 1.9% per year on average.

In terms of fuels, transport in India – as elsewhere in the world – is heavily dominated by oil (Figure 2.16), a notable feature being the very high share of diesel in overall transport oil demand (1 mb/d of diesel use representing 70% of the total in 2013). This level of diesel use is matched only in the European Union where it is attributable to the high share of diesel-fuelled passenger cars. There are a number of reasons for the high share in India. In road transport, freight vehicles (around 60% of road transport diesel use) and buses (around 35%)

dominate diesel use, while the subsidies for diesel in place until 2014 increased the share of diesel passenger cars in total car sales (although this proportion diminishes in the New Policies Scenario, following the removal of these subsidies). In the railway sector, too, two-thirds of energy consumption is diesel, despite several decades of work on electrifying railways. In our projections, India's transport oil demand climbs to 5.3 mb/d in 2040 and remains dominated by diesel, on the back of a strong increase in freight activity.

Figure 2.16 ▷ Transport fuel demand by type in the New Policies Scenario



The strong growth of transport energy demand, and the expectation of further growth, has sparked concerns over the consequences for oil security and air pollution in India. This led to the adoption of policies to promote the use of alternative fuels, such as biofuels, electricity and natural gas. Promoting the use of biofuels has a long history in India; but we project that the ambitious – albeit indicative – targets to reach a 20% blending of ethanol and biodiesel will not be achieved, primarily because of constraints on biofuels supply (see Chapter 3). In our projections, the share of biofuels in road transport liquid fuel demand climbs only slowly to 3% in 2040, from about 0.2% today, replacing some 0.18 million barrel of oil equivalent per day (mboe/d). India also has a National Electric Mobility Mission Plan 2020, to promote the use of electricity in Indian road transport by providing subsidies to support a target level of sales of 6-7 million hybrid and electric vehicles per year by 2020. Although the target encompasses all modes of road transport, market uptake of pure electric vehicles has so far been largely confined to scooters, with officially reported sales of 42 000 in 2012/2013. In the New Policies Scenario, the sales of electric scooters increase further, reaching a share of almost 2% in total sales of two- and three-wheelers in 2040, and displacing oil consumption of 7 kboe/d; but the spillover to passenger cars remains limited.

The use of natural gas in transport has been promoted since the 1990s, in particular in Delhi and Mumbai, to combat air pollution. While the stated targets were generally met, they were negated by the increasing proportion of diesel use and by the sheer growth in the number of vehicles. Nevertheless, India today has the sixth-largest fleet of natural gas vehicles in the world, mostly composed of taxis and buses, and an established refuelling network in several cities. The use of gas in road transport expands moderately in our projections, accounting for 0.2 mboe/d of demand by 2040.

Agriculture

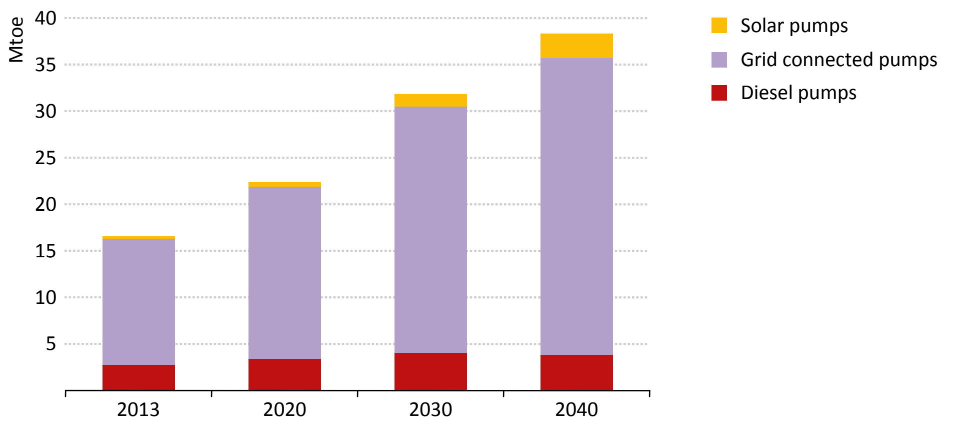
Despite the decline in the agriculture sector's contribution to India's GDP, it still engages directly half of the country's population and is also an important energy consumer, responsible for 15% and 18% of the total final consumption of diesel and of electricity, respectively. Although total food grains production in India has increased by around 35% since 2000, agriculture still faces multiple challenges relevant to the energy sector, particularly an inter-related knot of issues around inefficient pump sets, over-consumption of electricity (because of highly subsidised tariffs) and poor irrigation performance. In our projections, energy consumption in agriculture increases by 27 Mtoe to 50 Mtoe by 2040, with electricity accounting for 68% of the 2040 share and oil products (overwhelmingly diesel) a further 30%.

Different elements affect the evolution of agricultural energy demand in our projections. On the one hand, demand for food is expected to grow and diversify, as living standards rise and the population grows, increasing the need for fertilisers (see industry section). The agriculture sector is also likely to become increasingly mechanised: although modern techniques have already led to large improvements in productivity, there is significant scope for further gains. For example, tractor use is under 16 per 1 000 hectares in India compared with an indicator of 211 in Italy and 461 in Japan (Ministry of Agriculture, 2013). Farm mechanisation is generally expected to push energy consumption higher, although the pace of change will be limited by the fragmented nature of land ownership, which reduces the economies of scale that mechanisation can bring.

There are also significant energy efficiency gains to be had within India's irrigation system, one of the most extensive in the world and one that has supported the increase in cropping intensity of farmland. The system relies heavily on electric pumps (around 70% of the stock of pumps in operation [Ghosh and Agrawal, 2015]), mostly of very low efficiency (20-35%) (BEE, 2009). Moreover, flood irrigation, with an estimated water use efficiency of only 35-40%, remains the most widely used method (a significant reason why agriculture is responsible for a remarkable 90% of annual freshwater withdrawals). Tackling these two issues would help to reduce the over-use of electricity in the sector as well as reducing water consumption; but this is a challenging task for policy-makers, requiring a carefully integrated approach – as witnessed by the mixed results of efforts at reform in Andhra Pradesh, Gujarat and West Bengal, among others. The risk of unintended results is high. For example, a significant push to improve the uptake of efficient water pumps and to introduce solar water pumps are laudable efforts from an energy policy perspective; but if they are not accompanied by changes in agricultural and irrigation practices (requiring in turn a strong consultative and educational effort with farmers), they risk missing out on some of the potential gains, as well as increasing water consumption.

In the New Policies Scenario, the average efficiency of electric pumps is improved by around 25%, compared with today's levels, and more widespread adoption of drip irrigation techniques leads to further efficiency gains for irrigation. Oil consumption for irrigation remains essentially flat, as more and more diesel pump sets are replaced by electric ones – currently the sales of electric pump sets exceed sales of diesel pump sets by a factor of 2.5. By the end of the projection period, electricity meets close to 90% of the energy use for irrigation, with a rapidly growing share of demand being met by solar-powered pumps (Figure 2.17).

Figure 2.17 ▷ Energy demand for irrigation by source in India in the New Policies Scenario



Power sector

As outlined in Chapter 1, recent years have been marked by impressive achievements in the power sector in India, including a rapid expansion in generation capacity that was undertaken, in large measure, by the private sector, the introduction of policies to tap into large wind and solar power potential, a sharp rise in improving access to electricity and the strengthening and extension of the national transmission grid. The key missing component, vital to the future outlook, is distribution. The distribution utilities have been accumulating large losses because the average revenue per kilowatt-hour (kWh) of power sold is typically lower than the cost to the utility of the electricity they buy from the generating companies. Lacking financial resources, distribution utilities are unable to invest as much as they should to upgrade ageing and loss-prone parts of the network. Their financial situation also has operational implications for power supply, as it can deter distributors from purchasing electricity from costly peaking plants. This leads to load shedding and difficulties in meeting obligations to purchase power from renewable energy sources.

There is no single answer to the problems facing the distribution sector. End-user tariff increases are necessary, but they cannot offer a solution in isolation – not least because the affordability of electricity is a question of understandable political and social sensitivity. A suite of measures, with strong inter-linkages can move the system progressively towards full cost recovery, for example:

- Reliable and efficient procurement of fuel for the power sector, including auctioning of supply rights for coal (discussed in Chapter 3) and a more open market for gas.
- Concerted efforts to bring down the physical losses of electricity that arise across the transmission and distribution network.
- Reliable commitment to a competitive environment for power generation, allied with cost-effective policies to support renewables, both in terms of the choice of instruments used to secure additional capacity, and the regulatory and licensing conditions for investors.
- A system of permitting and approvals that gives a robust and transparent hearing to new generation and transmission projects, with a predictable timeframe.

On the revenue side of the equation, measures to improve the position of the distribution utilities include:

- Tackling the issue of non-technical losses, i.e. those arising from theft, non-payment and non-billing, and non-collection of payments for electricity consumed.
- Reducing cross-subsidisation between industrial, commercial and residential sectors, with adequate compensation from the state for any below-cost tariffs required by the state to be offered to specific groups, such as agricultural and vulnerable consumers.
- A regulatory environment, policed by well-staffed, well-trained and independent regulatory bodies, that compels the distribution utilities to pay consistent attention to improving their performance, while also providing an efficient and transparent governance framework for the system as a whole.

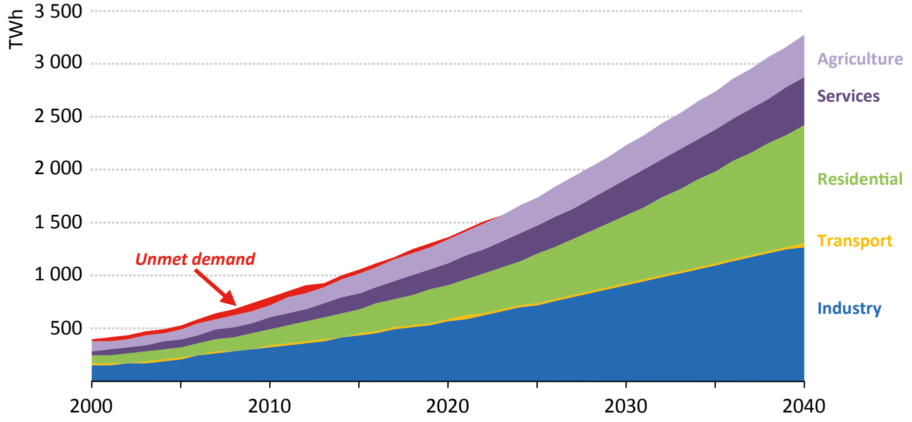
Policy intentions have already been expressed in relation to all these points and the projections in the New Policies Scenario assume progress in all these areas – albeit at a pace that reflects our judgement about the scale of the challenges involved and the likelihood of persistent state-by-state variations in their implementation. The net result is a system which does offer reasonable incentives for investment in generation and transmission capacity, sufficient to keep pace with India's rapidly growing needs.

Electricity demand

In the New Policies Scenario, electricity demand more than triples over the period to 2040, rising by 4.9% per year on average from 900 terawatt-hours (TWh) in 2013 to almost 3 300 TWh by the end of the projection period (Table 2.3). India accounts for almost 17% of the increase in global electricity demand from 2013 to 2040, an amount roughly equivalent to today's power consumption in Japan, Middle East and Africa combined. Per-capita electricity consumption grows from over 710 kWh to more than 2 000 kWh per year, an average annual growth rate of 4.0%.[9] Despite the growth, India's per-capita electricity demand remains well below the world average in 2040.

The anticipated increase in the reliability of power supply, including during times of peak demand, has widespread implications for the level of power consumption. It would lead to progressively less reliance upon, and ultimately less need for, back-up systems, whether large-scale captive power in the industry sector, or batteries plus inverters or small diesel generators in buildings.[10] It also releases some pent-up demand, as households expand their range of appliances, in the knowledge that they can be reliably used. In our projections, this unmet demand – an estimated amount linked to the incidence of load shedding in today's electricity supply – diminishes steadily over the coming years and disappears entirely by the mid-2020s (Figure 2.18). This occurs despite the large additional pressures that are put on the system by rising levels of access to electricity and strong growth in consumption from existing residential, commercial and industrial consumers.

Figure 2.18 ▷ Electricity demand by sector in India in the New Policies Scenario



Notes: Unmet demand is the energy deficit that results from load shedding expressed as a share of total final consumption. It is a conservative measure of unmet demand, not least because it does not include potential demand from people without access to electricity. Other energy sector is not shown as it is negligible.

9. This is different than the data reported by the Central Electricity Authority (CEA) as the *WEO* calculates per-capita electricity consumption as electricity demand divided by population while the CEA divides gross electricity generation by population. As such, CEA data for per-capita consumption are 957 kWh (2013/14).

10. The Central Electricity Regulatory Commission has estimated an installed capacity of 90 GW of small diesel generators across India. These generators are largely unmonitored and not covered by regulation or included in official statistics. However, IEA estimates the fuel (diesel) consumption of these generators as part of power generation fuel mix.

Table 2.3 ▷ Electricity demand by sector and generation in the New Policies Scenario (TWh)

	2000	2013	2020	2030	2040	2013-2040 Change	2013-2040 CAAGR*
Demand	**376**	**897**	**1 351**	**2 241**	**3 288**	**2 390**	**4.9%**
Industry	158	375	565	904	1 277	902	4.6%
Residential	79	207	329	647	1 115	908	6.4%
Services	46	133	207	332	450	318	4.6%
Transport	8	15	20	24	30	14	2.5%
Agriculture	85	160	222	324	401	241	3.5%
Other energy sector	0	6	8	10	13	7	2.7%
T&D losses	155	220	313	452	613	393	3.9%
PG own use	40	82	107	160	229	147	3.9%
Gross generation**	**570**	**1 193**	**1 766**	**2 848**	**4 124**	**2 930**	**4.7%**

* Compound average annual growth rate. ** Gross generation includes own use by power generators (PG), demand in final uses (industry, residential, services, transport and other) and transmission and distribution (T&D) network losses but does not include imports, which are minimal.

Industry remains the largest consumer of electricity in India. Industrial electricity demand more than triples over the *Outlook* period, though the overall share of industry in electricity consumption falls slightly from 42% in 2013 to 39% by 2040. The largest increases come from the steel and aluminium sub-sectors, which are responsible for 18% and 9% respectively of the rise in consumption. In the buildings sector (which includes residential and services), consumers take advantage of the improved quality of electricity supply to steadily increase their demands on the system, by an average of 5.8% per year. The share of electricity in residential energy consumption rises very quickly, from 10% in 2013 to 41% by 2040, in line with rising incomes, appliance ownership and demand for cooling. Peak demand for electricity, driven by residential demand, is expected to remain an evening phenomenon; a development that is reinforced by the increased reliability of power supply and the diminishing role for batteries and inverters (which at present effectively transfer some of the evening load to the daytime).

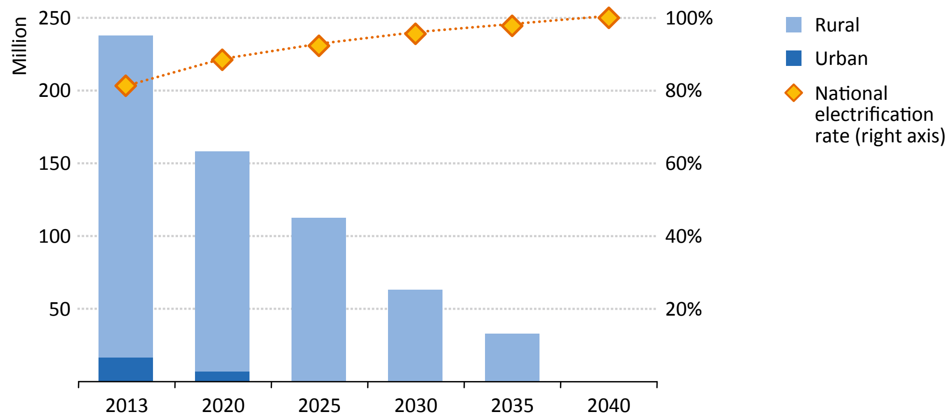
Consumption by agricultural end-users also rises; but the overall rise of 3.5% per year is tempered towards the end of the projection period as efficiency measures and more metering start to take effect. The share of agriculture in electricity demand falls from 18% in 2013 to 12% by 2040. Electricity demand in the transport sector is relatively small, at less than 1% of the total in 2040: rail is responsible for nearly all of the sector's electricity demand as electric vehicles make very small in-roads into the Indian market over the *Outlook* period.

Access to electricity

India makes major progress towards full household electrification in the New Policies Scenario and achieves universal access to electricity by the end of the projection period. The pace of change is fastest in urban areas, where universal access is reached by the mid-2020s, but slower in rural areas, where some 60 million people remain without access in 2030 (Figure 2.19). The government's goal of providing round-the-clock electricity access for all households is an important spur for accelerated action; but the target is difficult to achieve within the envisaged medium-term timeframe. Investments to expand the transmission and distribution system take some time to materialise. Moreover, putting in place all the necessary connections, mini-grids and off-grid systems becomes progressively more difficult the closer India gets to universal access, as the remaining households tend to be the hardest to reach: most Indian villages have some electrical connection today, but connecting the last remote households in the surrounding areas can be very costly. In addition, some households might voluntarily forgo adoption of electricity because of the monthly fees that come with it, particularly if supply is unreliable and outages are frequent.

In the New Policies Scenario, India's share in the global figure for people without access to electricity declines from 20% in 2013 to around 8% in 2030, as progress in India (and in developing Asia in general) is generally faster than elsewhere and much more rapid than in sub-Saharan Africa. Even though India is projected in this scenario to fall short of the Sustainable Energy for All target of universal access by 2030, this should not disguise the important achievements expected to be made, particularly in rural areas of India, where an additional 200 million people gain access by 2030. Over the entire projection period, around 580 million people gain access to electricity either through grid connections or through mini- and off-grid systems.

Figure 2.19 ▷ Population without access to electricity and electrification rate in India in the New Policies Scenario



The type of access that is provided depends on multiple factors, including the current state and coverage of the transmission and distribution systems, the plans to extend the grid and the availability of financing to realise these plans. In the New Policies Scenario, people living in urban areas gain access exclusively via grid extensions as this is the more economical option. Households close to areas of relatively high population density, i.e. in and around the centres of villages, tend to gain access through the grid as well; but for the remaining population living in rural areas, grid extension might be technically difficult or economically more costly than mini-grids or off-grid solutions.

The development of mini- and off-grid systems in rural India faces some important difficulties. This is an area for business model and technology innovation, but low tariffs for on-grid supply, often well below-cost recovery levels, constitute a major barrier, as they skew the economic calculation against off-grid projects. Most mini-grids are community-based projects or are run by private and social enterprises. The private sector is now playing a greater commercial role, usually through "fee for service" models, financed by banks and private equity. While this is promising, private investors tend to invest mainly in areas where consumers have the ability to pay without subsidies. Targeted support from the states or non-governmental organisations for small-scale projects remains essential. Moreover, technical knowledge is necessary for mini-grid operations and maintenance. In West Bengal for instance, mini-grid developments proved to be successful because provision was made for the involvement of qualified technicians to support the local level operators. In Chhattisgarh, a cluster approach involving structured maintenance networks, using (as far as possible) standardised systems has been adopted to reduce transaction costs (Palit, 2014).

Defining the respective roles of on-grid and off-grid technologies is important to achieve faster progress with electrification, as is the existence of an integrated and well co-ordinated strategy among the various public bodies involved (Ministry of Power, Ministry of New and Renewable Energy, Rural Electrification Corporation and State Electricity Boards) to ensure that state electrification plans can be sustainably financed, implemented and monitored. The affordability of power for the poorest households is an essential criterion if electrification is to bring sustained benefits in terms of welfare: metering, differentiated tariffs and better targeted subsidies for the poorest households can all help in this respect. Building in provision for electricity to support productive uses, i.e. for small businesses, can also contribute strongly to financial sustainability, as these businesses become an important source of economic activity and revenue.

Electricity supply

The power system in India has to cope with a number of challenges over the *Outlook* period. Power generation capacity needs to be expanded to serve rapidly growing power demand and to overcome the shortages which causes regular load shedding. Peaking capacity and flexible power plants need to be added to the fleet to meet demand at any time, improve the reliability and quality of supply and integrate variable renewable energy technologies into the system. The evolution of the generation mix needs to reflect energy security concerns, affordability and environmental compatibility. Moreover, electricity transmission and distribution networks require massive investments to transport growing amounts of power, bring down the notoriously high losses, deal with increasing volatility in power generation and connect to the grid millions of people without access to electricity. How India addresses these challenges is primarily a question of policy; the long-term trends presented in this section are very sensitive to the successful implementation of reforms.

The development of the Indian power sector – despite there being little power trade with neighbouring countries – is also dependent on a range of interactions with the rest of the world, including fuel procurement, technology co-operation and imports, as well as flows of investment and investment finance. In the New Policies Scenario global power generation grows by over 16 000 TWh over the *Outlook* period and India accounts for almost a fifth of this growth. Similarly India accounts for nearly 50% of the increase in global coal-fired power plant capacity and relies on a growing share of internationally traded coal to fuel these plants – before 2020 India becomes the largest coal importer in the world. India also becomes a key player in terms of utility-scale solar PV, accounting for one-sixth of newly installed PV capacity in the world to 2040.

Building a power station in India typically comes at a lower cost than in OECD countries and therefore India's share in cumulative global power generation investment over the *Outlook* period is lower than its share in global power demand growth. Nonetheless, in the New Policies Scenario one out of ten dollars invested in the power sector worldwide is invested in India over the projection period. Rapidly growing power generation and continued reliance on coal as the fuel of choice for generation also make India a significant contributor to growing carbon-dioxide (CO_2) emissions from the power sector. In the period to 2040, India's CO_2 emissions from power generation grow nearly two-and-a-half-times; making its power sector the second-largest emitter from power generation in the world.

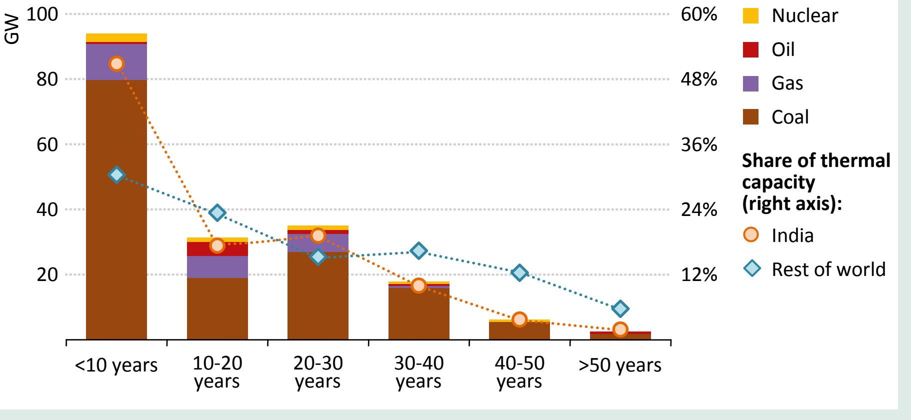
Power generation capacity

Installed power capacity in India grows three-and-a-half-times, from 290 GW in 2014 to over 1 075 GW in 2040, the latter being roughly equivalent to the installed capacity in the European Union today (Table 2.4). Capacity increases faster than generation; this is due in large part to installations of variable renewables, which become an increasingly important part of the Indian power system. Wind and solar power have lower capacity factors than thermal plants, meaning that additional capacity is needed to meet demand when the wind does not blow or the sun does not shine. Moreover, in an effort to reduce the shortage in peaking capacity, the projections require a substantial increase in the number of power plants (typically gas turbines or large engines) that might run for only a few hundred hours a year. Plants fulfilling such a balancing role, with their relatively high variable costs, face a significant risk of being insufficiently compensated by financially weak power off-takers, a factor that could seriously impede investment.

Box 2.7 ▷ A fleet to last a lifetime

Just over half of the world's thermal power plant fleet is less than 20 years old, but in India this share is two-thirds (Figure 2.20). The relative youth of much of India's power generation fleet means that relatively few of these plants will reach the end of their technical lifetime over the *Outlook* period. In the case of coal plants, over half of Indian coal capacity has been added during the last ten years (while globally only 38% of the coal fleet is less than ten years old). The comparison of the age profile of nuclear power is similarly striking: nearly two-thirds of the Indian nuclear capacity is less than 20 years old, while, on a global level, only 15% of the fleet was built during the last 20 years – mostly in non-OECD countries.

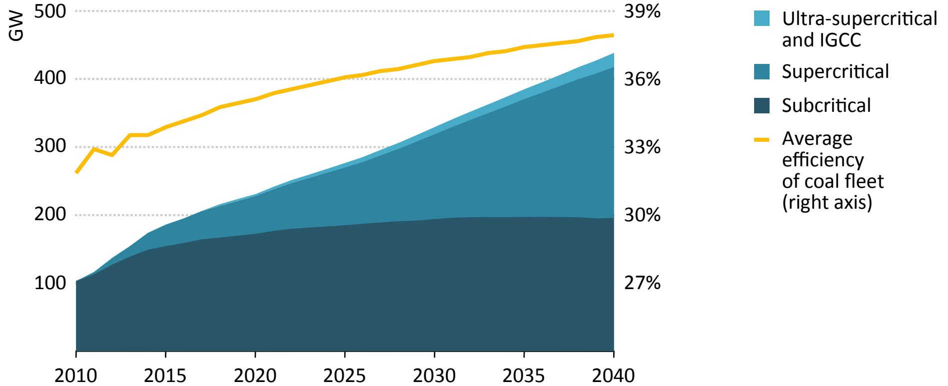
Figure 2.20 ▷ Age profile of thermal capacity in India, end-2014



Replacing retiring power stations (a major issue in OECD countries) is therefore a smaller challenge in India. Of the 100 GW of capacity that is retired over the period to 2040, around 60 GW are thermal plants. However, as older plants typically have a smaller unit size, the number of plants retiring is larger than the capacity figure suggests. This provides an opportunity in many cases to bypass lengthy and costly land acquisition processes by installing large and efficient power stations on existing sites. Indian authorities are actively discussing the idea of prematurely retiring old, inefficient plants and replacing them with larger supercritical stations in order to expand capacity rapidly. The remaining 40 GW are renewable energy plants with shorter technical lifetimes (the assumed lifetime of wind and solar PV is around 25 years). Thus, although almost all the currently installed wind and PV capacity will have to be replaced or re-powered before 2040, the investment equation in India is essentially a simple one: to ensure that capacity additions keep pace with consumption, rather than also having to keep up with large-scale retirements.

Coal-fired power plants – half of which have entered into service during the last ten years (Box 2.7) – remain the backbone of the Indian power system. In our projections, the coal fleet increases by around two-and-a-half-times, reaching almost 440 GW in 2040, by which time India has the second-largest coal fleet in the world (after China), having overtaken the United States in the early-2020s. The technological composition of the coal fleet also changes markedly. Today over 85% of the coal plants are based on subcritical boiler technology, performing poorly in terms of their conversion efficiency. Several supercritical plants have come online in recent years, as domestic manufacturing capability for such boiler types has been boosted, accounting for the remaining 15% of the coal fleet. By 2040 the share of supercritical plants in the expanded fleet has increased to around half of the total and there are also some ultra-supercritical plants and integrated gasification combined-cycle (IGCCs) built in the latter half of the projection period (Figure 2.21). The shift towards supercritical technology effectively boosts the country's average coal plant efficiency from 34% today to 38% in 2040 – a notable shift given India's endowment of low quality (high ash) coal.[11] Gas-fired capacity increases five-fold, reaching over 120 GW in 2040. Gas plants are crucial for improving the reliability of power supply, being typically used for load-following operation and balancing, key roles in system operations.

Figure 2.21 ▷ Coal-fired power plant capacity by technology and average efficiency in India in the New Policies Scenario



Although permitting and public acceptance remain a challenge, especially for large dams, over the *Outlook* period India increasingly taps its large hydropower potential, with capacity growing from 45 GW to nearly 110 GW in 2040 (including small hydro plants). Hydro capacity is heterogeneous, with run-of-river plant essentially serving as baseload, while reservoir-based hydro plants tend to operate in times of high load. Variable renewables,

11. The high ash content of Indian coal does not impede the installation of supercritical and ultra-supercritical technology but it inevitably results in an efficiency loss compared to what would be achievable with low ash coal. Use of modern technology requires plants to be designed according to the properties of a specific coal type.

like wind power and especially solar PV, are set to grow rapidly over the period (Table 2.4). Wind power reaches around 140 GW in 2040, up from 23 GW today. But it is really solar PV that underpins the rise in renewable energy development, with capacity boosted from just 3.5 GW in 2014 to over 180 GW in 2040 (Spotlight). Solar PV capacity is available during the day when load is relatively high, but in an evening peaking system, like that in India, solar PV does not contribute to meeting peak demand, a key reason why its expansion needs to be complemented by additional peaking capacity.

SPOTLIGHT

India's solar target: how high can you go?

The Indian government has announced plans to bring the country's solar capacity to 100 GW in 2022. This target is a five-fold increase over the previous target of 20 GW, representing a step-change in India's solar ambition. From 3.7 GW of solar capacity in 2014, the target would require annual additions averaging 12 GW per year for the next eight years. The annual installations of solar PV by a single country have, to date, never exceeded the 11 GW reached by China in 2013. Of the targeted 100 GW, around 60 GW are envisaged to come from utility-scale plants, with the remainder being rooftop PV installations and other small-scale and off-grid installations. Plans for the utility-scale installations are the most advanced, with the centrepieces being the National Solar Mission (which plans to add more than 15 GW of capacity) and the proposal for a series of solar parks, large-scale solar facilities across various states, with up to 500 MW of capacity each. In addition, various state governments have come up with their own targets and support schemes. Initiatives to roll out rooftop PV are less advanced. They primarily focus on net-metering policies and improving the cost and availability of financing (see also Chapter 3).

Achieving these ambitions will require that a challenging set of issues related to land acquisition, remuneration, network expansion and financing are overcome. A rapid increase in solar installations, at least in the early years, would also be beyond India's current solar panel manufacturing capability (around 2.8 GW per year), although there is ample PV manufacturing capacity in other countries. The financing issue is particularly problematic, as the estimated $170 billion in investment is, in all likelihood, beyond the capacity of the domestic financial sector; but attracting international capital introduces new challenges, such as foreign currency risk (see Chapter 4). With these constraints in mind, we project that solar PV capacity reaches 40 GW in 2022, nearly twelve-times today's capacity, increasing at a rate of deployment that sources the bulk of the panels from local manufacturers and allows for the build-up of an installation industry without overheating supply chains. There is upside potential as well as downside risk to our projection: what is unarguable is that India's solar targets have already served one vital purpose, making a powerful statement of intent that solar power shall be a new and potentially transformative technology in India's energy mix.

Table 2.4 ▷ Power generation capacity by type in India in the New Policies Scenario (GW)

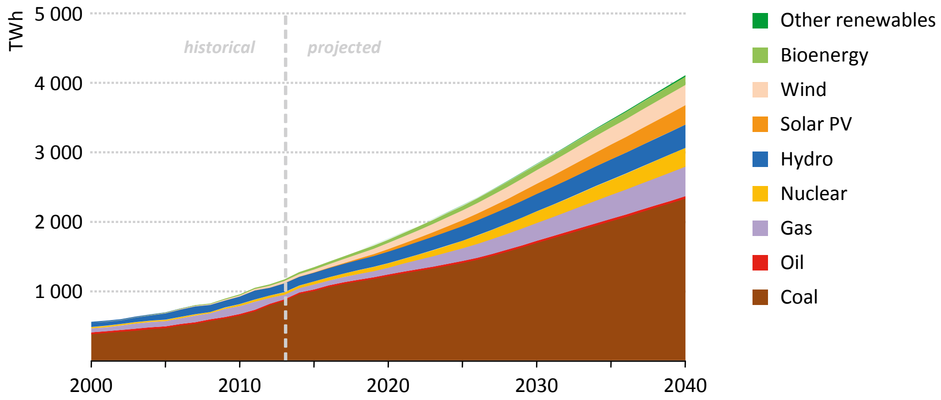
	2000	2014	2020	2030	2040	Shares 2014	Shares 2040	CAAGR* 2014-2040
Fossil fuels	84	204	280	419	576	71%	53%	4.1%
Coal	66	174	230	329	438	60%	41%	3.6%
Gas	11	23	41	76	122	8%	11%	6.6%
Oil	7	7	9	13	15	3%	1%	2.9%
Nuclear	3	6	10	24	39	2%	4%	7.6%
Renewables	27	79	147	304	462	27%	43%	7.0%
Hydro	25	45	58	83	108	15%	10%	3.5%
Wind	1	23	50	102	142	8%	13%	7.2%
Solar PV	0	3	28	100	182	1%	17%	16.4%
Other	0	7	11	18	30	3%	3%	5.5%
Total	**113**	**289**	**436**	**746**	**1 076**	**100%**	**100%**	**5.2%**

* Compound average annual growth rate.

Power generation

Electricity production increases from 1 193 TWh in 2013 to over 4 100 TWh in 2040, meaning that power output in India is larger than power generation in the European Union by 2035 (although, because of a higher rate of losses, Indian power demand overtakes European levels only a few years later). In terms of output, by 2040, India has the third-largest power system in the world, after China and the United States. The power generation mix also becomes increasingly diverse. Today, nearly three out of every four units of electricity are generated by coal-fired power plants (Figure 2.22). By 2040, even though coal-fired power generation expands by two-and-a-half-times (and only China produces more electricity from coal than India), coal's share in the power mix drops to 57%, with renewables, nuclear and gas all increasing at high rates. Nuclear power complements coal in baseload power generation, increasing its share in the mix from around 3% today to 7% in 2040. Gas-fired power plants are currently suffering from lower than expected supply of domestically produced gas, for which higher cost imported LNG has been no substitute. Rather than run the plants at a large loss, many combined-cycle gas turbines (CCGTs) are operating only at very low load-factors. This situation is partially reversed over the medium term, as imported LNG becomes available at a more competitive price. Gas gains further ground in the power mix over the longer term, although – due to the continued relatively high cost of the fuel in India – gas-fired plants do not produce baseload power. Instead, they flexibly follow the daily load pattern and meet demand peaks. This essential balancing role helps gas-fired power generation to increase more than six-fold over the *Outlook* period, reaching 430 TWh by 2040. The share of gas in the Indian power mix nearly doubles to 10% in 2040.

Figure 2.22 ▷ Power generation by source in India in the New Policies Scenario



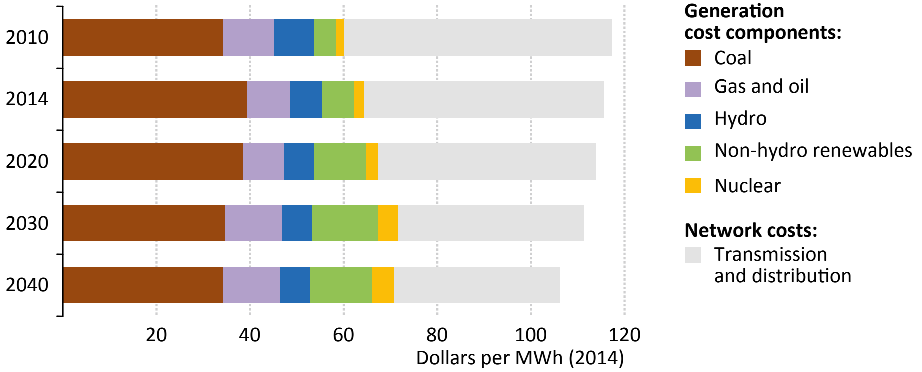
Power generation from renewable energies – with the exception of hydro – plays a minor role today in the power system in India. However, this is set to change substantially over the *Outlook* period, with non-hydro renewable power output growing twelve-fold, to 720 TWh. The share of all renewables in power generation increases from 17% today to 26% in 2040, with wind and solar PV together accounting for 65% of the growth in renewable power output. The government's focus on solar PV deployment, in combination with the good solar resources, makes the country the second-largest producer of electricity from solar PV installations by 2040, overtaking first the United States and then European Union around 2030. Wind energy deployment is primarily at onshore sites, with offshore wind power only picking up modestly in the latter half of the projection period. The variable nature of solar PV and wind power generation requires complimentary system arrangements to optimally integrate these sources, affecting the operational characteristics of the other power plants and triggering an expansion of flexible power sources. The growth of hydropower helps in this respect, although hydropower plants form a varied group, with some installations providing baseload power, while others operate more flexibly to meet fluctuations in demand. Overall, hydropower still provides a third of the renewables-based electricity in 2040. Small hydro plants, especially those in mountainous parts of northern India, play an important role in providing access to electricity in remote villages.

CO_2 emissions from power generation in India grow nearly two-and-a-half-times over the *Outlook* period, reaching 2.3 gigatonnes (Gt) in 2040 (up from just under 1 Gt in 2013). The share of the power sector in the country's total emissions decreases from half today to 45% in 2040. Renewable energy deployment and the use of more efficient coal-fired technologies bring the CO_2 emissions-intensity down by 30%, from 790 grammes of carbon dioxide per kilowatt-hour (g CO_2/kWh) to 560 g CO_2/kWh.

Power prices and generation costs

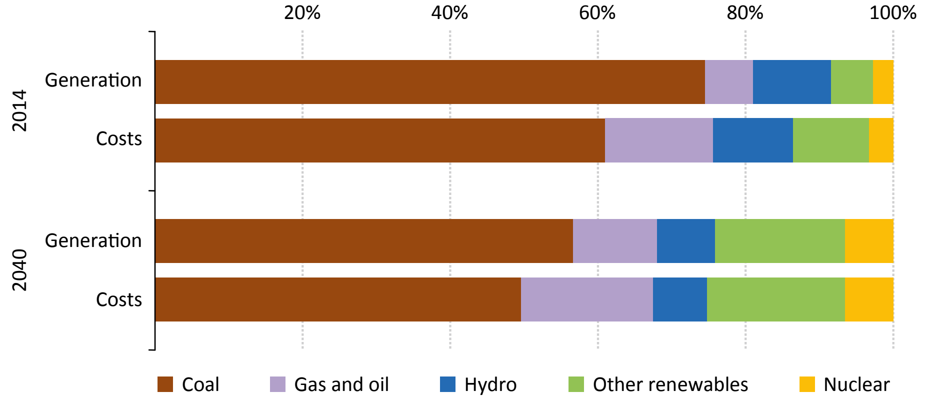
The affordability of electricity is an understandably sensitive issue in India, making it essential to keep in check the underlying costs of power generation and the costs of transmission and distribution. The average cost of power generation increases from around $65 per megawatt-hour (MWh) today to just over $70/MWh in 2040 (Figure 2.23). Despite the multiple benefits that come with the deployment of non-hydro renewables – chiefly solar PV and wind power – they put upward pressure on India's power generation costs. India is an evening peaking system and therefore, despite abundant sunshine, solar PV does not have a significant capacity credit. Consequently, solar PV primarily displaces conventional generation during the daytime – saving fuel costs – but reduces only slightly the amount of dispatchable capacity needed to serve the evening peak. Some similar observations are true for wind power, although its capacity credit is slightly higher. As a result, in 2040, non-hydro renewable energy accounts for 19% of the average cost of power generation, slightly above its contribution to the country's output. To contain the cost increases from non-hydro renewables deployment, their support mechanisms must be designed in a way that captures the benefit of falling technology costs over time and avoids over-compensation.

Figure 2.23 ▷ Components of the delivered cost of an average unit of power in India in the New Policies Scenario



For gas-fired plants, the situation is slightly different, though – even more so than in the case of non-hydro renewables – they also contribute less to generation than to costs: in 2040 the share of gas-fired generation in India's generation mix stands at 10% while its share in average generation costs amounts to 17% (Figure 2.24). However, gas-fired plants play a key role in the reliability of power supply, as both their technical and economic characteristics favour flexible operation, i.e. being able to quickly ramp output up and down. Their disproportionately high share in generation costs is therefore justified by the additional value they provide to the system. Coal-fired power generation costs decrease over the *Outlook* period, despite increasing coal prices and deployment of more capital-intensive technologies, as upward pressures on these costs are contained by the marked improvements in conversion efficiency realised over time. Coal-fired power contributes substantially more to output than to overall costs, helping to keep electricity tariffs affordable for consumers in a period when India is adding more costly sources of power (although the falling technology costs of solar and wind reduce this effect over time).

Figure 2.24 ▷ Share of total power generation costs versus share of generation in India in the New Policies Scenario



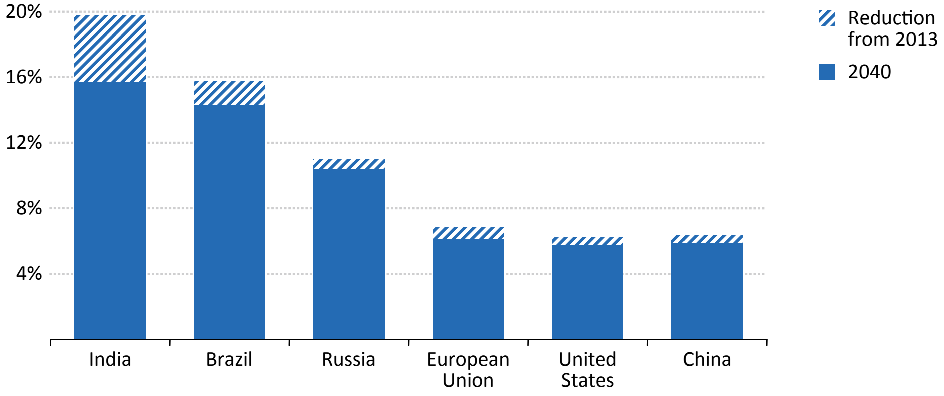
The structure of costs, in terms of their variable and fixed components, also undergoes a considerable transformation. Today, with large reliance on coal, power generation costs are primarily composed of (variable) fuel costs. However, nuclear, hydro, wind and solar PV grow rapidly; these technologies are very capital-intensive and have minimal variable costs. Coal-fired power generation also becomes more capital-intensive with the focus shifting to supercritical technology. The higher capital cost is justified by higher efficiency, reducing fuel expenditure. In 2040, 55% of the total power generation costs are fixed, compared with 53% in 2014. This shift in the cost structure does not directly impact the affordability of power, but it makes power tariffs slightly more stable, as generation costs are less exposed to the volatility of fuel prices.

In addition to the generation costs, the total system cost includes network costs for the transmission and distribution of electricity. On a per-MWh-basis, the average total system costs can be interpreted as a proxy for average end-user prices (excluding taxes and levies). Despite rising average generation costs, the average system costs decrease slightly over the long term, as declining network costs provide relief to the system. Standing at around $115/MWh today, system costs stay flat over the medium term and then decline to around $105/MWh in 2040. Continued reduction of technical and commercial losses brings network costs down over time, despite grid expansion and the growing volume of power transmission. Improving the efficiency of the networks and bringing their costs down is the key to countering rising power generation cost and keeping power affordable for all.

Transmission and distribution

India has five regional network zones that are connected to each other, forming a national grid. Transmission lines – which transport power over large distances from the power plants to the demand hubs – account for only 5% of the network length. The rest consists of distribution lines, which deliver power over the last few kilometres to the consumers. India's network suffers from one of the highest shares of loss (of electricity generation) in the world (Figure 2.25). Network losses are driven by technical and commercial factors. The technical losses typically increase with ambient temperatures and distance between generation sources and demand centres. Ageing and poorly maintained networks are more prone to high technical losses than modern and efficient installations. On the commercial side, theft, unmetered consumption and inadequate revenue collection add to network losses. In our projections, India takes large steps in bringing down network losses over time, with the share dropping from a national average of 20% today to less than 16% in 2040. Reducing commercial losses helps re-establish the financial viability of the transmission and distribution companies, giving them the funds to carry out much needed network investments.

Figure 2.25 ▷ Network losses and reduction of losses in India and in an international context in the New Policies Scenario



Apart from bringing down the losses, India's transmission and distribution network faces a number of additional challenges over the *Outlook* period. Although a growing role for distributed renewables, notably rooftop solar PV, allows capacity to be built nearer to the point of consumption, the network still needs to be expanded both to accommodate growing power demand, to integrate the growing share of utility-scale wind and solar projects, to improve interconnection with neighbouring power systems, and also to reach those settlements and households that currently do not have access to electricity. In our projections, the length of the network increases by over 70% in the period to 2040. This expanded grid permits more efficient dispatch of the power plant fleet, thereby reducing generation costs. An additional challenge, but also a large opportunity, is the modernisation of the metering infrastructure.

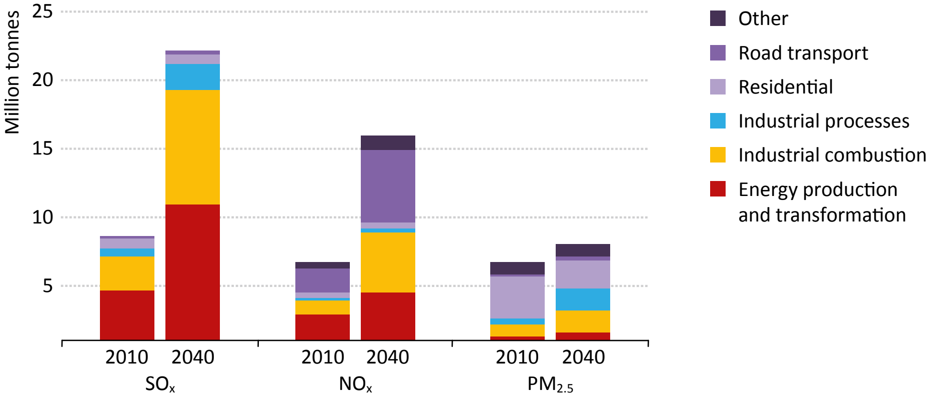
If successful, this would not only contribute to reduced commercial losses, but could also allow India to roll out smart metering and other information technology-based solutions to establish the ground for demand-side management and the introduction of smart grids.

Implications for air quality

Local air pollution is a large and growing problem in India that already takes a heavy toll on health (see Chapter 1). For this analysis, we have examined the evolution of the main relevant pollutants, sulphur oxides (SO_x), nitrogen oxides (NO_x) and fine particulate matter[12] ($PM_{2.5}$), assessing how the different energy scenarios presented in this *Outlook* impact on the amount of each pollutant emitted, to help identify the improvements that can be made in the energy system to manage these issues.[13]

Over the period to 2040, emissions of SO_x rise to more than two-times their current levels, stemming primarily from coal combustion in power plants and, to a lesser extent, industrial facilities (Figure 2.26). The strong increase in demand for mobility and increasing car ownership lead to a similarly large rise in NO_x (road transport emissions register a three-fold increase), compounded by emissions from industrial combustion and the broader energy sector, which also grow robustly. $PM_{2.5}$ emissions show much more modest growth; almost two-thirds of the estimated releases of $PM_{2.5}$ are related to the incomplete combustion of biomass by households and industry and, with biomass substituted for LPG for cooking, emissions are reduced by 30% in the residential sector. The benefits are offset, to a degree, by a robust increase in emissions from industry, where biomass use remains significant. Energy production and transformation makes the largest contribution to the increase in total emissions, which double in the period to 2040.

Figure 2.26 ▷ Emissions of NO_x, SO_x and $PM_{2.5}$ by sector, 2010 and 2040



12. Particulate matter is categorised by the size of the particles, $PM_{2.5}$ represents the size of the particles in micrometres and is considered the most harmful to health.

13. The analysis of the impacts of future local air pollution trends has been developed in collaboration with the International Institute for Applied Systems Analysis, Austria.

The health impacts of increasing pollution are considerable. The rise in outdoor $PM_{2.5}$ emissions alone is calculated to lead to a reduction in life expectancy of more than seven months (this is in addition to the 16.8 months in reduced life expectancy that is a result of current $PM_{2.5}$ levels). This corresponds to a 140% increase in premature deaths, which reach 1.7 million in 2040. Indoor air pollution, from the continued though diminished use of solid biomass for cooking, could be expected to add considerably to this number. In addition, the rise in ground-level ozone leads to crop losses. By 2040, the increase in ground-level ozone gases leads to a 13% decrease in wheat yield and will have adverse impacts additionally on soybean, rice and maize crops.

The threat of an unbridled increase in air pollution is well known to Indian policy-makers, who have announced plans to implement an air quality index in ten cities, giving daily updates on the pollution status. The existing legislation, the Air Prevention and Control of Pollution Act, dates back to 1981 (with amendments in 1987). Policy-makers are planning to introduce improvements and updates to bring it into line with India's changing economic realities. As things stand, many of the standards in force were set in the 1980s and technological improvements since then mean that the standards are now comparatively low by international standards. Current standards for coal-fired power plants, for example, govern only particulate matter and set a target ranging from 150 milligrams per cubic metre (mg/m^3) to 350 mg/m^3, compared with 30 mg/m^3 in China. Standards for ambient air quality set a target annual average limit for $PM_{2.5}$ that is four-times higher than that recommended by the World Health Organization.

Chapter 3

Outlook for India's energy supply

Unlimited needs, limited resources

Highlights

- The sheer size of the increase in energy demand in India means that it mobilises its energy supply resources on all fronts. In our projections to 2040, low-carbon energy – led by solar and wind power – grows rapidly, from a relatively low base, but domestic production of coal, rising at almost 4% per year, makes by far the largest contribution in energy terms. Yet the increase in domestic energy production is far below India's consumption needs, and by 2040 more than 40% of primary energy supply is imported, up from 32% in 2013.

- Coal production increases to 930 Mtce (roughly 1 750 Mt in volumetric terms) in 2040, making India second only to China among global producers. Accomplishment of a faster rate of growth, such as the ambitious volumetric target to raise output to 1.5 billion tonnes by 2020, is constrained by the concentrated structure of the coal industry, issues over land use and permitting, and infrastructure bottlenecks. Reforms to the system of coal procurement and contracting underpin new mining investment and an efficient allocation of coal to consumers, including an expansion of competitively priced imports in parts of coastal India. India becomes the world's largest importer of coal before 2020 and imports rise to over 400 Mtce by 2040.

- India's oil production tails off to around 700 kb/d, as limited resources and relatively high costs constrain new oil projects. The result is a rapid rise in net oil imports, to 9.3 mb/d by 2040, and high reliance on the Middle East for imported crude oil. India's refinery output grows, but is increasingly dedicated to the domestic market.

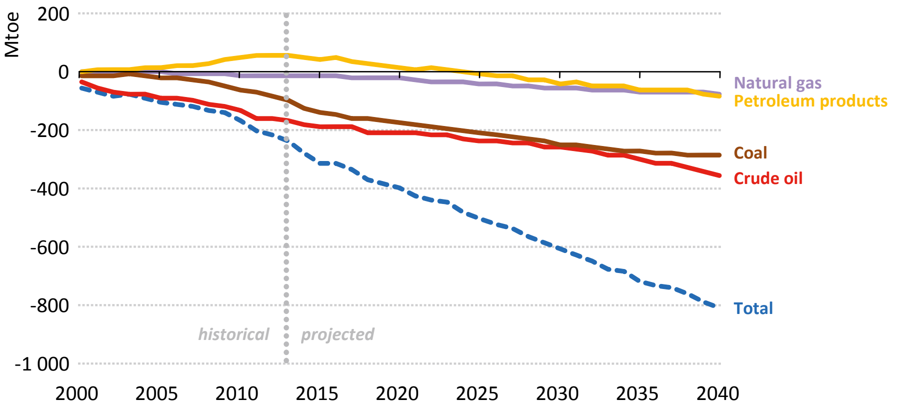
- Gas production rises to 90 bcm in 2040, but this would require an adjustment to (or premium on top of) the current formula that determines the price paid to domestic producers, or investment risks falling short – especially for complex offshore projects. The gas balance is filled by rising imports of LNG, although India's relative proximity to the Middle East and to Central Asia offers scope for new pipeline links.

- Wind and solar power are abundant and increasingly cost effective. The target to reach 175 GW of renewable capacity (excluding large hydro) by 2022 is a strong statement of intent, galvanising new projects, manufacturing and installation capabilities. Deployment is slowed, in practice, by issues with land use, grids and financing, but the expansion of solar generation capacity to 2040 is second only to coal in our projections. Additions of hydropower and nuclear power plants have fallen well short of planned levels in recent years, and issues of permitting and public acceptance could continue to hold back investment: recent international agreements have though eased constraints on nuclear co-operation.

Energy supply in India

The pace at which energy consumption is expected to expand means that India mobilises supply on all available fronts in the New Policies Scenario. Deployment of wind and solar power increases at the fastest pace, but the production of all domestic sources of energy is higher in 2040 than in 2013, with the sole exception of oil, where India's resource limitations come into play. Yet domestic energy production is not sufficient in aggregate to keep up with demand, leaving a growing gap that needs to be filled by imported fuels (Figure 3.1, Table 3.1). Increases in domestic coal production keep the need for coal imports at least partly in check. But net oil imports rise dramatically, to reach 9.3 mb/d by 2040, an import dependence of greater than 90%.

Figure 3.1 ▷ Fossil-fuel trade balance in India in the New Policies Scenario



Note: Mtoe = million tonnes of oil equivalent.

Coal

Coal quality, resources and reserves

Total proven coal reserves in India amount to 87 billion tonnes – roughly equivalent to 140 years of current output – of which hard coal (steam and coking coal) makes up 95%, and the remainder is lignite.[1] Total coal resources (inferred and indicated), including deposits that are yet to be proven, are almost two-and-a-half-times larger, at 213 billion tonnes (BGR, 2014). Coal is not evenly dispersed across India. Most can be found in the east of the country, with two-thirds of Indian reserves located in the states of Jharkand, Odisha and Chhattisgarh (Figure 3.2 and map at Figure 3.7).

1. In order to provide a consistent underlying basis for modelling, data from the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) on reserves and resources are used for all countries in the *World Energy Outlook*. The data in this section are different from the Indian coal ministry's *Coal Inventory of India* report (which states 307 billion tonnes of resources and 132 billion tonnes of reserves) as the BGR applies a recovery factor to the in-situ reserves (accounting for the fact that typically not all in-situ reserves are extractable) and deducts cumulative past production volumes.

Table 3.1 ▷ Energy production in India in the New Policies Scenario

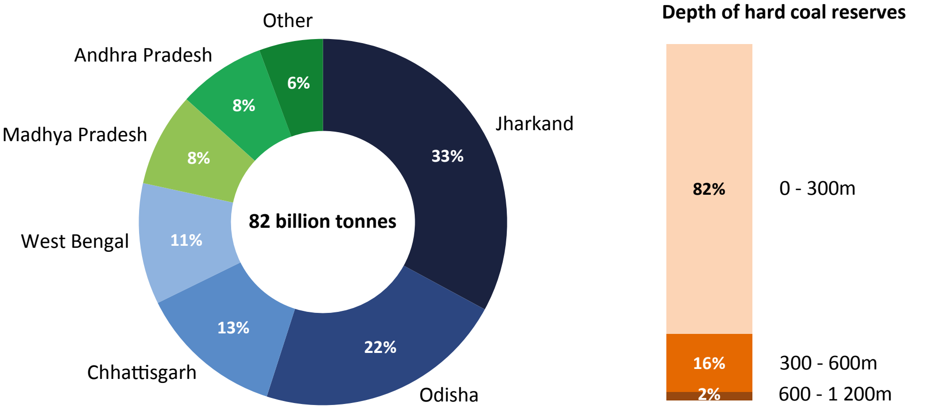
	Unit	2000	2013	2020	2030	2040	2013-2040 Change	2013-2040 CAAGR*
Oil	Mtoe	37	43	35	31	31	-12	-1.2%
	kb/d	771	917	734	678	725	-192	-0.9%
Natural gas	Mtoe	23	29	32	46	75	46	3.6%
	bcm	28	35	38	55	89	55	3.6%
Coal	Mtoe	131	238	298	443	648	410	3.8%
	Mtce	187	340	425	632	926	586	3.8%
Nuclear	Mtoe	4	9	17	43	70	61	7.9%
Renewables	Mtoe	155	204	237	274	297	93	1.4%
Hydropower	Mtoe	6	12	15	22	29	16	3.2%
Bioenergy	Mtoe	149	188	209	217	209	20	0.4%
Other renewables	Mtoe	0	4	13	35	60	56	11.0%
Total production	Mtoe	**351**	**523**	**619**	**836**	**1 121**	598	2.9%
Total demand	Mtoe	441	775	1 018	1 440	1 908	1 133	3.4%
Share of imports	*%*	*20%*	*32%*	*39%*	*42%*	*41%*	*n.a.*	*n.a.*

* CAAGR = compound average annual growth rate. Notes: kb/d = thousand barrels per day; bcm = billion cubic metres; Mtce = million tonnes of coal equivalent.

Indian coal reserves are mostly shallow, at a depth of up to 300 metres, and are typically exploitable using surface mining methods. However, as some of these coal reserves are located below settlements or dense forests (areas for which surface mining approval is difficult to obtain), going underground might ultimately prove the only feasible solution if these deposits are to be tapped, as it avoids resettlement and forest clearing. Coal occurring at depths greater than 300 metres is usually economically extractable only with underground mining techniques. Coal companies in India have extensive experience in surface mining, but so far, state-of-the-art underground mining – even though already applied in some mines – has made limited in-roads. Worldwide, mining companies have been successful in economically and safely extracting coal at great depths, but unlocking the full potential of India's coal endowment will require significant technological improvement of its mining industry.

Indian hard coal is mostly bituminous, with relatively low moisture but high-ash content. Three-quarters of current coal production has ash content of 30% or greater, with some of the highest ash coals approaching 50%. In comparison, coal traded on the international market rarely exceeds 15% ash content. The majority of the ash in Indian coal is so-called inherent ash, i.e. small particles of mineral matter that are embedded in the combustible part of the coal. Contrary to free ash – mineral impurities that are related to the extraction process – inherent ash cannot easily be removed from the coal. The high-ash content reduces the calorific value of the coal. Most of the coal currently produced in India falls in a range of 3 500 kilocalories per kilogram (kcal/kg) to 5 000 kcal/kg. This is markedly lower than the average heat content of coals typically found in other large producing countries, such as China, United States or Russia.

Figure 3.2 ▷ Hard coal reserves by state in India



Sources: BGR; Inventory of Coal Resources of India; IEA analysis.

Costs

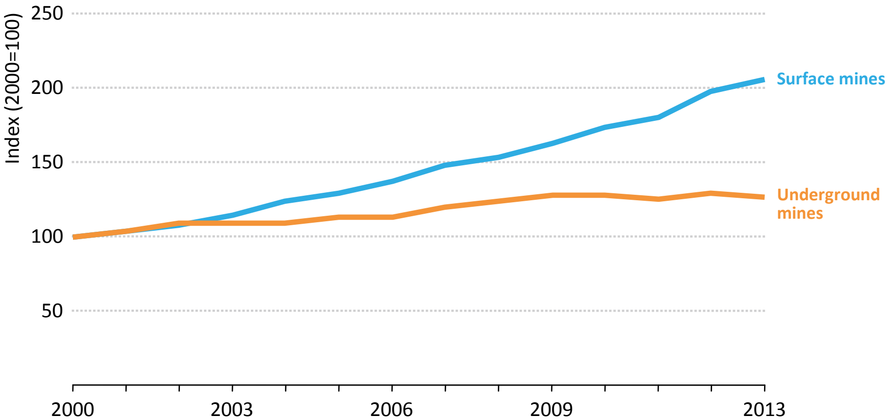
Production costs for coal in India fall in a wide range, with some large open-cast mines producing coal for less than $15 per tonne, while other small high-cost underground mines have costs in excess of $150 per tonne. Generally speaking, primarily due to low productivity, coal from underground mines in India is much more costly to produce than coal from surface mines, even when adjusted for energy content (which tends to be higher in underground mines). At current coal prices of $40 per tonne on average for domestic coal and $80 per tonne for imported coal (both adjusted to 6 000 kcal/kg), the majority of underground mines in India are outright unprofitable (see section on coal market and industry structure). Driven by surging coal demand, the primary goal of state-owned coal companies in India is maximisation of output to provide coal to power stations and to industry rather than optimising financial returns. Consequently, the rents of open-cast mines are used to cross-subsidise costly production from deep mines.

In 2013, labour productivity (expressed as output per miner shift in tonnes) in surface mines was fifteen-times higher than in underground mines. This is partly due to surface mines having experienced a doubling in labour productivity since the early-2000s (Figure 3.3). In contrast, underground mines still perform poorly and their labour productivity has grown at a much slower pace. An average Indian coal miner produces less than two-and-a-half thousand tonnes (kt) of coal per year, while an Indonesian counterpart is at least 50% more productive, a miner in China produces more than 5 kt per year and an Australian worker mines up to 13 kt per year on average.[2] In India wages are still low and consequently the mines exhibit a higher labour-intensity than elsewhere. While open-cast mines, in

2. Miner productivity is a function of the relative cost of labour and capital: countries with high labour cost typically have a highly mechanised and hence capital-intensive coal mining industry while substitution of capital for labour is less prevalent in countries with low wage levels.

particular, have increasingly made use of larger equipment, gaining economies of scale, in India's underground mines, efficient longwall methods are still rare. Underground mines primarily rely on room-and-pillar methods, which allow only a fraction of the coal in a deposit to be extracted (with this method, tunnels of coal are carved out of the seam, while part of the coal remains in place as "pillars" to support the roof).

Figure 3.3 ▷ Productivity evolution in the coal mining sector in India



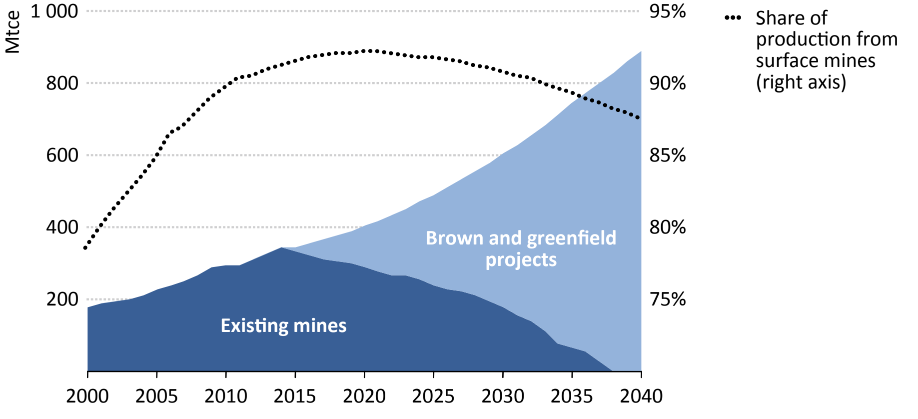
Sources: IEA analysis; Coal Directory of India.

Due to generally labour-intensive production methods and the high share of open-cast mines, the two fundamental cost drivers are wages and the oil price, factors which lead to a moderate increase in costs over the *Outlook* period. With continued strong gross domestic product (GDP) growth, real wages are expected to experience upward pressure, although mining companies can counter this effect by increasing mechanisation and using more efficient equipment and machinery, i.e. by pushing up capital costs and improving productivity (with India's strong growth in coal production over the *Outlook* period, the primary goal of mechanisation and efficiency gains would not be to reduce the workforce but rather to increase output per miner). The second cost driver is oil: oil products are widely used in open-cast mining, primarily as a fuel for earth-moving equipment but also as an input to certain explosives. Rising oil prices, as envisaged in the New Policies Scenario, put upward pressure on costs at surface mines (although this effect can, to some degree, be offset by more efficient equipment or additional use of electric draglines). India is also likely to see some diversification away from oil use because of the rise in mechanised underground mining in the latter half of the projection period, which tends to be powered by electricity.

Production prospects

India produced 340 million tonnes of coal equivalent (Mtce) of coal in 2013, of which 291 Mtce were steam coal, 35 Mtce coking coal and 14 Mtce lignite, making India the fifth-largest producer of coal (in energy terms; in volume terms India is the third-largest) after China, United States, Indonesia and Australia. In the New Policies Scenario, Indian coal production grows to 925 Mtce in 2040 (Figure 3.4), moving the country into second position among global coal producers (both in energy and volume terms), behind only China. Steam coal production accounts for almost all of the growth. India's endowment of coking coal is comparatively small and thus growth in coking coal production is subdued, the volume increasing from 35 Mtce in 2013 to nearly 50 Mtce in 2040. Lignite production, mostly taking place in Gujarat, Rajasthan and Tamil Nadu, grows two-and-a-half-times (from a low base) over the *Outlook* period, and reaches around 35 Mtce.

Figure 3.4 ▷ Coal production by type of mine and share of surface mines in India in the New Policies Scenario



Sources: IEA analysis; Coal Directory of India.

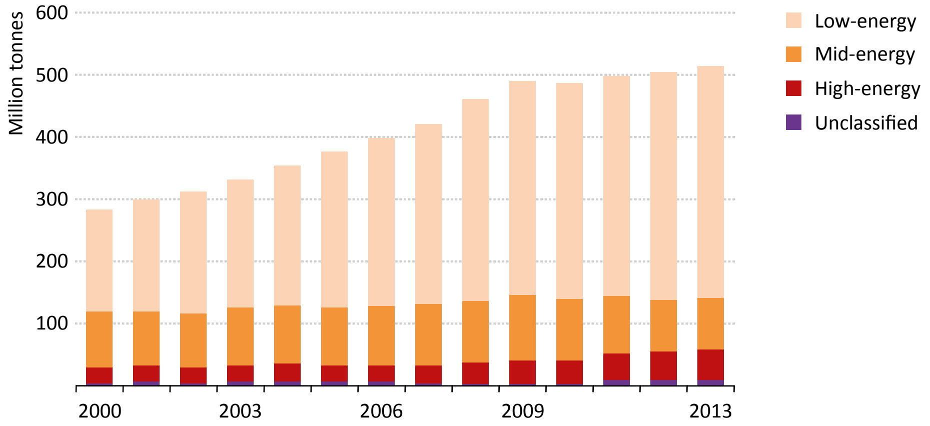
Most of the production in our projections comes from surface mines, which have been the main source of growth in supply over the last decade, although the share of underground mining does rise steadily from the mid-2020s and reaches 12% by 2040.[3] The shift towards underground mining is increasingly necessary to sustain production growth. Even where the depth of the reserves may theoretically allow for surface mining, in many cases underground mining may be preferred as it avoids disturbance of the land and settlements over the deposits, accelerating mine approval. The New Policies Scenario assumes that efficient and highly mechanised underground technology (as found for instance in China, Australia or United States) is gradually adopted by the coal industry in India over the *Outlook* period; the speed at which new technologies are adopted in practice will be related to the extent to which the sector is opened to competition.

The established trend of decreasing energy content per tonne of coal production, the result of focussing on shallower, easier-to-mine deposits of low-energy coal, is projected

3. There are currently over 530 active coal mines in India of which more than half are underground operations. The large number of underground mines is in stark contrast to their disproportionately small contribution to national coal production of less than 10%, indicating their tiny size.

to continue. A push for rapid output expansion could exacerbate this trend in the medium term, as it could also result in less careful waste rock removal, essentially increasing (free) ash content and contributing to the deterioration in calorific values. This highlights the need for the policy focus to be not only on increasing tonnage, but also on the energy content of output. Since the early-2000s, production of high- and mid-energy coal (more than 4 200 kcal/kg) has stayed broadly flat while production of low-energy coal (less than 4 200 kcal/kg) has more than doubled (Figure 3.5), meaning that miners in India have to extract around 1.5 tonnes of coal to get the same amount of energy as that contained in one tonne of Australian coal. In the longer term, the deterioration of energy content is projected to be somewhat contained by technological advances in mining equipment and by tapping deeper deposits, some of which have higher calorific values. But the low quality of produced coal remains a problem throughout the *Outlook* period, putting additional strain on the transportation system, as increasing volumes need to be shipped, and holding back improvements in the efficiency of power plants.[4]

Figure 3.5 ▷ Evolution of steam coal production by coal grade in India



Note: The high-energy coal category has calorific values of more than 5 600 kcal/kg, gross air-dried (GAD); mid-energy coal with has values between 4 200 - 5 600 kcal/kg (GAD); and low-energy coal contains less than 4 200 kcal/kg (GAD).

Sources: IEA analysis; Coal Directory of India.

The coal production increase over the *Outlook* period corresponds to an average annual growth rate of 3.8%, one of the highest growth rates for coal production in the world, topped only by some smaller emerging producers. This, nonetheless, falls short of the levels targeted by the Indian government, which has announced the objective of mining 1.5 billion tonnes of coal by 2020 (Box 3.1). The reasons why this target is missed in our projections (and why output growth has been sluggish since 2009, frequently falling short

4. Ash disposal is also a problem as fly ash utilisation (e.g. in the cement or brick industries) absorbs only around 60% of the total yield. Policies are proposed to require fly ash use in the construction industry within 500 km from coal plants.

Box 3.1 ▷ A 1.5 billion tonne question for the coal outlook

In early 2015, the Indian government announced plans to increase the country's coal production to 1.5 billion tonnes by 2020, a highly ambitious goal, given that the country produced 603 million tonnes (Mt) in 2013. Reaching the target would require that domestic coal production increases by almost two-and-a-half-times over a seven-year period (or by 14% per year on average). By way of comparison, in the period 2006-2013 Indian coal production increased by around a third (or by 4% per year on average). In the New Policies Scenario, the rate of growth does pick up to 2020 – based on the assumption that policies regarding licensing, land acquisition and approvals speed up mine developments – but India falls short of the targeted volume. Our projections have coal production rising to over 800 Mt in 2020, a growth rate of 4.6% per year.

Reaching 1.5 billion tonnes of coal production by 2020 is difficult, but not inconceivable. It would, though, imply that all expansion plans are fulfilled without delay and all involved actors – federal and state governments, mining and railway companies – co-ordinate seamlessly so that approvals and licences are issued speedily, mines are developed on schedule and additional coal can be transported. Reaching the target would also require the consent of the people affected by coal mine and railway line development.

India's state-owned mining company CIL is pivotal to this process, slated to contribute 1 billion tonnes of output to the government's target, with the remainder coming from smaller state-owned mining companies and the captive mines that are currently being auctioned. CIL has released a detailed roadmap showing where the additional tonnes are to come from. They have identified 908 Mt of capacity, from existing projects (18%), from projects under implementation (62%) and from future projects (20%), while another 92 Mt are yet to be identified.

If the production target were to be reached, this would have dramatic implications for global coal markets, as exporters around the world are betting on India absorbing the slowdown in Chinese coal imports. In the New Policies Scenario, India becomes the world's largest coal importer by 2020, despite a marked increase in production. If coal production in India reached 1.5 billion tonnes in 2020, the country would be self-sufficient in steam coal, cutting imports entirely. Coal projects in Australia, Indonesia and South Africa that target the Indian market would lie idle and extend the current situation of overcapacity on the international market. With Chinese appetite for imported coal diminishing, India disappearing as an importer would leave Southeast Asia as the only significant demand growth centre for internationally traded coal. The region is far too small to absorb all the additional production and, consequently, prices would remain depressed for a long time to come.

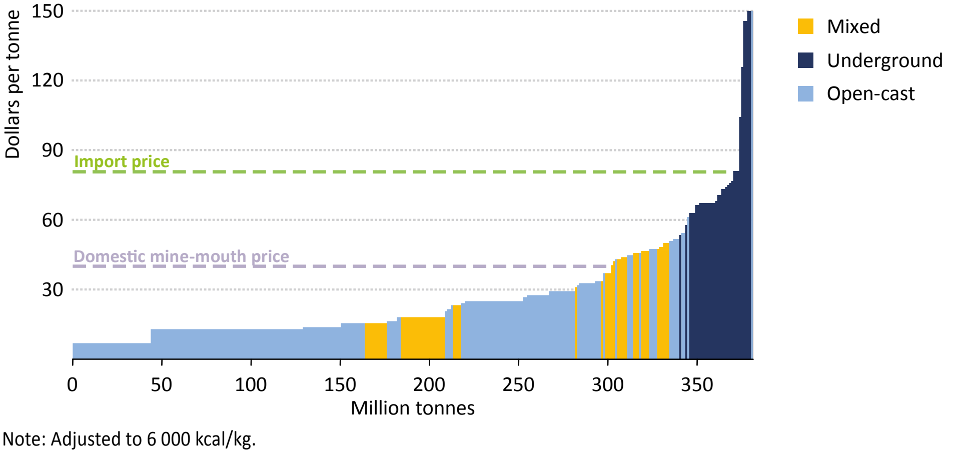
of demand) are related to a series of challenges facing the coal industry in India. The structure of the industry, dominated by state-owned Coal India Limited (CIL), is highly concentrated, and opportunities for new players are very limited (see next section). There are often delays in bringing new mining capacity on-stream due to difficulties with permitting – especially for land acquisition and permission for forest clearing. India is very densely populated, and surface mine development, in particular, affects large areas of land, requiring either people to be resettled, forest to be cleared or arable land to be rendered unproductive. Once operations have begun, in some cases transport infrastructure bottlenecks impede mines from increasing their production as they are unable to ship additional volumes. In some parts of the country, imports become cheaper than domestic coal, with competition between them determining the optimal domestic production level.

Coal market and industry structure

In India, coal allocation and pricing are influenced by the government. The state currently exercises control over more than 90% of production and full control over marketing of domestic coal. CIL has a dominant position, producing roughly 80% of India's coal via eight subsidiary companies of different sizes, of which the largest two, South Eastern Coalfields Limited and Mahanadi Coalfields Limited, together account for around half of CIL's coal yield. Singareni Collieries Company Limited (SCCL), not under CIL's umbrella, is the second-largest public coal company in India, contributing less than 10% to the country's coal output. Hitherto, private players could participate in coal production only if they acquired a "captive mining block", which are specified coal reserves which the buyers can extract for their own use, for example in power generation, steel making or cement production. Recently the Indian parliament has passed the Coal Mines Special Provisions Act, which is primarily concerned with the re-allocation and auctioning of the cancelled captive coal blocks (see Chapter 1). However, a key feature of the Act is that, in theory, mining licenses can be granted to private players without end-use restriction, opening the door to private sector commercial mining in the future. The New Policies Scenario assumes implementation of this Act, gradually leading to greater diversity of ownership in the coal industry and increased competition.

Prices for coal are set by CIL (and SCCL) and depend on the quality and type of coal. The quoted prices typically apply to so-called "coal linkages" – a kind of long-term contract for coal supply. They generally discriminate between different consumers of coal, with power generators typically receiving coal at more favourable rates than industrial users. Coal is sold at the mine mouth, with freight cost borne by the buyer. Around 12% of the annual output of CIL and SCCL is not sold under the linkage regime but instead is marketed on a spot market-like platform, called "e-auction". Prices realised in the e-auction markedly exceed the fixed prices of the linkages regime: for instance, in 2013, CIL received on average $42/tonne for coal sold in the e-auction, a sales price almost 50% higher than the average quoted price for coal linkages in that year. Coal from domestic mines is sold below market value in India, meaning that only in a few coastal locations, far from the domestic coal fields, can coal from the international market be obtained at a more attractive price than the delivered price of domestic supplies. Converted to a heating value of 6 000 kcal/kg, Indian coal was sold at around $40/tonne on average in 2013 at the mine mouth (Figure 3.6). Adding $20-30/tonne for railway transport to a coastal location would imply a delivered coal price of $60-70/tonne. Imported coal with the same energy content delivered to a coastal power plant would have cost at least $75-85/tonne in 2013. This means an implicit (domestic) coal consumption subsidy of $5-25/tonne or $2-10 billion per year (if the situation were to persist, the subsidy would rise to $5-25 billion in 2040). The quoted prices for coal linkages distort market signals and are one of the reasons why capital allocation to new mining projects has been insufficient, contributing to the growing shortfall in output. The system of pricing has raised concerns about possible abuse of dominant position, which are re-enforced by the non-transparent way in which coal linkages are allocated. In response, the government is considering moving to a system of auctions for new linkages, with all players being able to participate (in a rapidly growing coal market, there will be many new linkages available for auction). This mechanism was proposed by an inter-ministerial committee in late April 2015. In theory, the auction price of the coal linkages should be close to parity with international coal prices.

Figure 3.6 ▷ Indicative domestic mining cost curve, 2013



Note: Adjusted to 6 000 kcal/kg.

As it stands, the spread between imported coal prices and domestic coal prices has repercussions in the end-use sectors, particularly in the power sector. This leads to inequalities between power companies and to financial hardship for power plants that have to buy expensive imported coal. With an increasing share of imports, the system would become less and less financially sustainable. In the New Policies Scenario, average Indian mine-mouth coal prices are set to increase over the *Outlook* period from around $40/tonne in 2013 to $60/tonne in 2040 (adjusted to 6 000 kcal/kg). Upward pressure comes from rising mining costs, but also from the increasing use of market-based instruments to determine prices – for example, the more widespread use of auctions for linkages – leading to a convergence over time between domestic and international prices.

The pace of reform in the Indian coal industry is likely to be slow. The main state-owned companies have been reluctant to countenance structural changes that would introduce new players to the market. The unions representing the labour-intensive mining sector, with around 400 000 people directly employed in public sector mining companies, fear that introducing competition and private participation would lead to job losses and pay cuts. Consequently they, too, often oppose attempts at reform, with strikes that can lead to marked production losses.

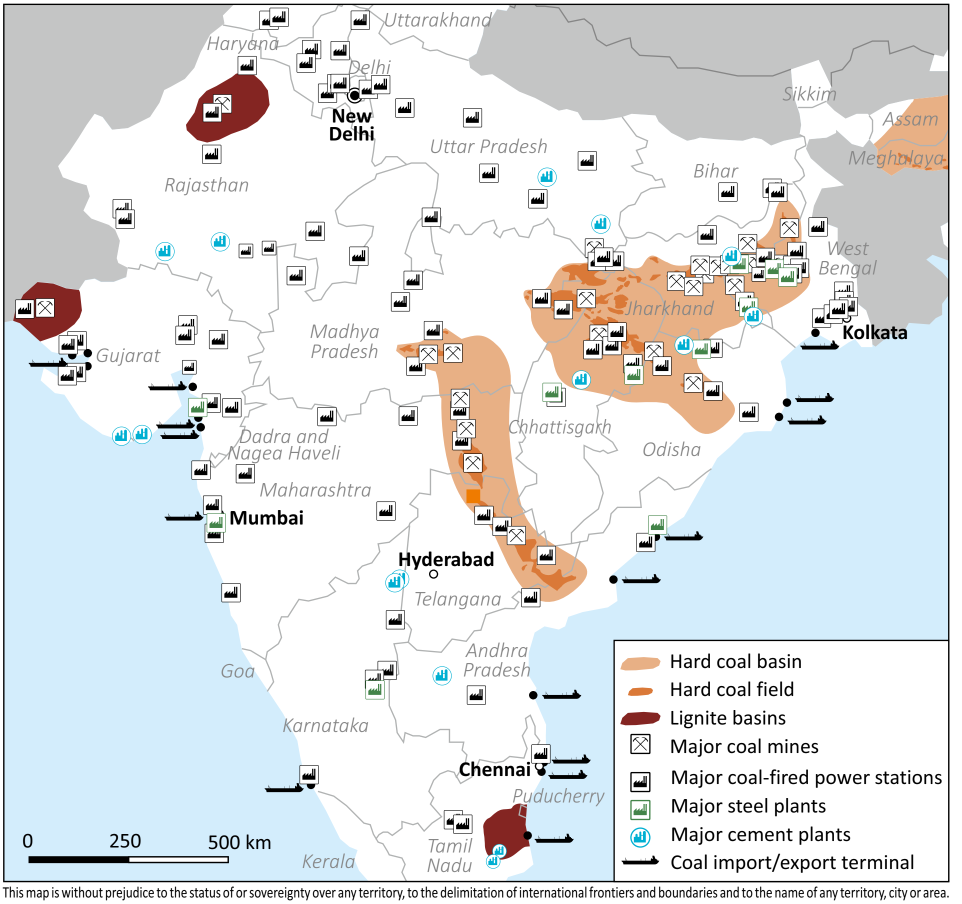
Auctioning of coal linkages, increasing competition by allowing for private sector participation in coal mining and streamlining the bureaucratic process with respect to mine development have all been identified in Indian policy as desirable developments. Implementation of these policy intentions is reflected in our New Policies Scenario and helps to overcome the market distortions in the power sector and to increase mine output. Adequate price signals also trigger productivity gains in currently uneconomic mines or the idling of too costly operations. The envisaged increase of competition, as more private investment comes to the sector, including foreign direct investment, helps to facilitate technology transfer and innovation, an important step given the role of new technology in countering mining cost escalation through productivity gains, increasing the share of underground mining and tapping more geologically difficult deposits. The reliability of supply, the price and the quality of coal are among the primary risks borne by investors in coal-fired power plants in India: alongside other measures in the power sector (discussed in Chapter 2), improving the conditions for investment in coal mining also serves to mitigate power sector investment risks and contributes directly to the reliability of electricity supply.

Transport and handling infrastructure

With coal production primarily concentrated in the eastern half of the country, there is a geographical mismatch between the location of producers and consumers (Figure 3.7). While there are clusters of power stations near the coal fields, other plants are scattered across the country, located closer to power demand hubs in order to save on the cost of electricity network expansion and to enhance power system reliability. Moreover, state-level energy policy favours a balanced distribution of power stations across the country.

Consequently, large amounts of coal need to be hauled from the mines to the various end-users all over India. The primary mode of transportation is by railway, accounting for around 55% of coal movements. Railways are economic for long-distance transportation and every tonne of coal moved by rail travels more than 500 km on average. Shorter distance transport, roughly a quarter of the country's coal movements, is carried out by truck. Typically truck transport is economic only for distances of less than 200 km and it often leads to congestion and additional air pollution. Consumers located close to the mines receive coal by merry-go-round systems (exclusive, closed-loop, coal railway systems) or conveyor belt. Some power plants or industrial works on the coast can also receive coal directly from seaborne vessels.

Figure 3.7 ▷ Main coal-mining areas and coal infrastructure in India



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

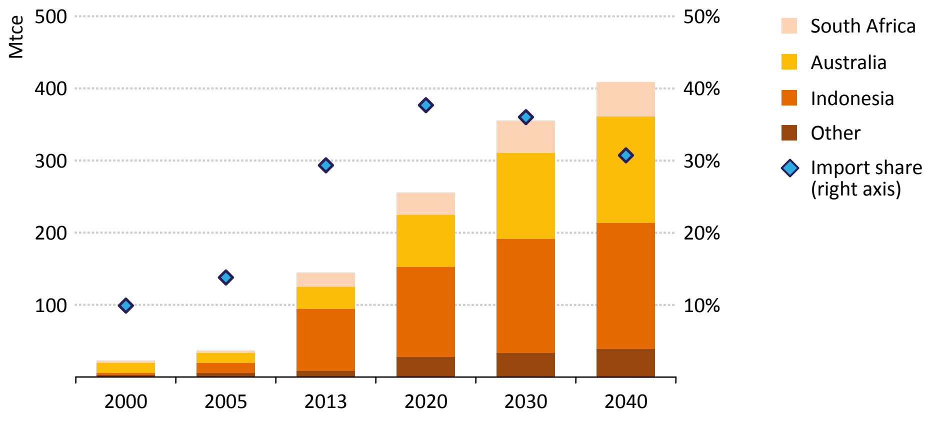
Bottlenecks in transport infrastructure have contributed to past coal shortages. Despite mining investment generally lagging behind, in some cases it is the lack of access to railway or inadequate access to other forms of transport that is hampering output growth and delaying mining investments. Railways are operating at full capacity on some critical freight corridors often holding up coal shipments. The understandable social priority accorded to passenger transport, together with cross-subsidies that involve freight transport paying for lower passenger fares, has the effect of slowing down coal movements and pushing up freight tariffs. Investments in access links, additional tracks and rolling stock are needed to accommodate growth in coal demand and must be financed. In relation to the prospective growth in imports, India currently has at least 250 million tonnes per annum (Mtpa) of port handling capacity. Thus, port infrastructure to handle imports is currently sufficient, but rail connectivity (to distribute coal further inland) has not kept up with port capacity growth and will need to be expanded to allow for increasing imports.

The growth in low-energy coal production puts particular additional stress on the transport infrastructure, as it has to handle ever-higher volumes of product, only part of which provides more energy. Coal washing can help to alleviate this by removing a part of the ash. India has around 130 Mtpa of washing capacity installed. Private players, in particular, have set up independent washeries, as coal washing is mostly profitable in India, due to the long transport distances. Washing costs amount to $3-4/tonne and, depending on how much ash is being removed, becomes profitable for transport distances over 700 km. Washing is supported by regulation that mandates that coal transported for more than 750 km (500 km from 2016) must have ash content of less than 34%.

Coal imports

Over the last decade India has increasingly tapped the international market to procure fuel for its power plants and industrial works, putting the country among the world's largest importers of coal. The rise in imports came as domestic production failed to keep up with surging coal demand. Indian imports reached 144 Mtce in 2013, of which 70% were steam coal and the remainder coking coal. Imports are projected to continue to increase over the *Outlook* period, to reach 410 Mtce in 2040 (Figure 3.8). In the New Policies Scenario, India becomes the largest global coal importer before 2020. Although coking coal imports remain essential for the rapidly growing steel industry, the majority of the growth in demand comes from power plants providing baseload power for the electricity sector. India has a favourable geography, with a long coastline and several low-cost coal exporters within reasonable distance for economic seaborne transport.

Figure 3.8 ▷ Coal imports by origin in India in the New Policies Scenario

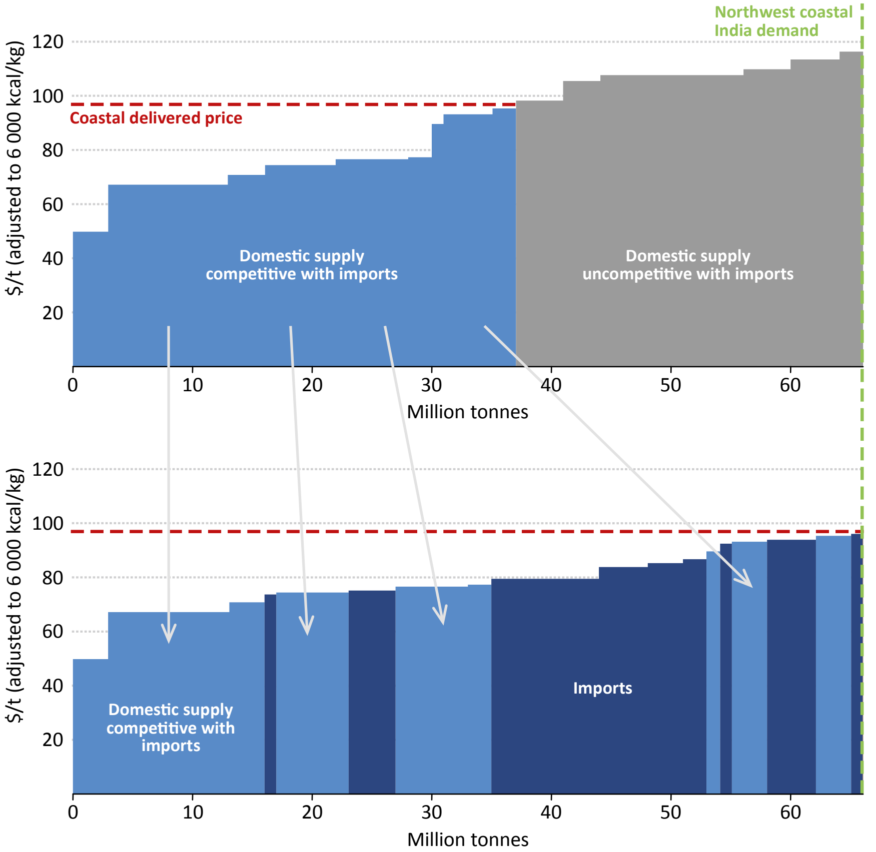


Indonesia is the main exporter to India, currently accounting for around 60% of imported coal. Indonesia is also the closest major coal exporter and thus benefits from a transport cost advantage, especially on the east coast. It remains a key player in the Indian market, but loses market share as steam coal from Australia gains ground. In 2040, only 45% of the Indian coal imports come from Indonesia. From a transport cost perspective, South Africa is the natural exporter to India's west coast. Once the main supplier to Europe, South Africa's exports have shifted to the east, with India now accounting for the largest share of its shipments. Moreover, some of the higher ash coals from South Africa suit Indian power plant boilers well and are typically available at a discount to market rates. South Africa continues to target Indian buyers as the size of the European market dwindles. Its share in the Indian import market essentially stays flat but volumes triple from 18 Mtce today to over 53 Mtce in 2040. With Indonesia and South Africa producing steam coal almost exclusively, Australia is the primary supplier of coking coal to India. Australia's main competitors in the coking coal trade, Canada and the United States, face substantially longer transport distances, creating a cost disadvantage. Only Mozambique, ramping up its total coking coal exports from 3 Mtce in 2013 to 20 Mtce in 2040, can challenge Australian exporters on a cost basis. For the moment, Australia chiefly ships coking coal to India but, from the mid-2020s, steam coal exports gain in importance, accounting for over 40% in 2040. Projects in Australia's Galilee Basin, some of which are being developed by Indian investors, will provide additional export coal in the longer term, but challenges regarding environmental concerns and the financing of the mines and infrastructure remain.

Indian coal import dependency has trebled over the last decade, reaching 30% in 2013. The share of imports is projected to increase further, peaking at 38% (in energy terms) around 2020, however, by 2040 it returns to today's levels as Indian domestic production takes a higher share of incremental demand. Some imported coal is currently transported long distances inland in order to alleviate fuel shortages, but this comes at a major cost to the users, as the transport distances add markedly to already higher prices of imported coal. In our projections, this situation eases over the medium term and inland transport distances for imported coal go down.

With the envisaged narrowing of price differentials between domestic and imported coal (resulting from increasing domestic mining cost and a larger share of market-based coal pricing), in some coastal regions imported coal becomes cheaper than certain domestic coals. Particularly in northwest India, we estimate that imports would be competitive with some domestic coal supply (Figure 3.9). In the long run, the region thus becomes a key arbitrage point, playing an important role in the pricing of internationally traded coal too. Under these circumstances, a continued share of imports is beneficial to the Indian economy, helping to keep coal supply costs down across the country. Coal imports do not give rise to significant energy security risks: disruptions to supply have been few and far between in the international coal market (unlike oil and gas) and, in any event, India sources its needs from a variety of producers. In addition, an increasing share of imports stems from vertically integrated Indian companies procuring their coal needs from their own projects, for instance in Australia or in Mozambique. India's drive to increase domestic coal production can be justified (or challenged) on a number of grounds, but to go so far as to aim for complete self-sufficiency in coal would be to adopt an expensive policy, without offsetting gains in terms of energy security.

Figure 3.9 ▷ **Indicative cost of coal delivered to northwest coastal India in the New Policies Scenario, 2030**



Note: The upper graph shows a case in which India's entire north-western coastal demand is served with domestic coal, with much of the domestic supply cost (the part labelled "Domestic supply uncompetitive with imports") exceeding the anticipated price level that can be achieved if imports serve part of the demand. The lower graph shows how a mix between cost-competitive imports and domestic coal ("Domestic supply competitive with imports") results in a lower delivered price.

Oil and natural gas

Resources and reserves

India is heavily reliant on imports for the bulk of its crude oil supply. Its smaller natural gas sector is likewise dependent on imports. The mismatch between domestic resources and needs is particularly stark in the case of oil: proven reserves of 5.7 billion barrels (out of the total remaining recoverable resources of 24 billion barrels) compare with annual crude demand that is already at 1.4 billion barrels and rising every year (Table 3.2).

Table 3.2 ▷ Oil resources by category in India, end-2014
(billion barrels)

	Ultimately recoverable resources	Cumulative production	Remaining recoverable resources	Remaining % of URR	Proven reserves
Conventional onshore	15.3	4.4	10.9	71%	3.6
Tight oil	3.8	0.0	3.8	100%	0.0
Shallow offshore	12.5	5.7	6.8	54%	1.2
Deep offshore	2.8	0.0	2.8	99%	1.0
Total India	**34.4**	**10.2**	**24.3**	**71%**	**5.7**

Notes: Data include crude, condensate and natural gas liquids. URR = ultimately recoverable resources.

Sources: IEA databases; BGR (2014); USGS (2012a, 2012b); OGJ (2013); BP (2015); Rystad Energy AS; India Ministry of Petroleum and Natural Gas.

If India's oil resources appear meagre next to its needs, the same cannot really be said for natural gas, for which remaining recoverable resources stand at a much healthier 7.9 trillion cubic metres (tcm). Around half of this is conventional (almost all offshore) gas and half is unconventional, in the form of shale gas and coalbed methane. The rate at which produced reserves have been replenished (through exploration and development activities that turn resources into proven reserves) has been slightly negative in the case of oil in recent years, but positive in the case of gas: in the past seven years, India has produced some 280 billion cubic metres (bcm) of gas while adding more than 330 bcm to proven reserves, excluding the offshore KG-D6 find.

For a country that is short of hydrocarbons, India still has a considerable amount of unexplored potential. A number of sedimentary basins have either no or scanty data and require additional geo-scientific exploration for better assessment of resource potential. Areas identified by the Indian authorities as either "prospective" or "potentially prospective", i.e. awaiting significant levels of exploration, extend over some 1.1 million square kilometres (km^2) of the almost 1.8 million km^2 that make up India's 26 onshore and shallow water sedimentary basins. India's deepwater territory, also largely unexplored, adds another 1.3 million km^2. The sense of under-explored potential is reinforced by the drilling record. Roughly 3 000 wells have been drilled in India's offshore basins, at an average density of one well per 146 km^2, which is a low intensity compared with other offshore basins (and certainly with the US Gulf of Mexico, which has been drilled with an average density of one well per 14 km^2). Getting the incentives right for an increase in exploratory activity, through sufficiently attractive licensing and pricing arrangements, may have only a limited effect on India's oil balance, but could have a much more significant impact on domestic gas supply.

Table 3.3 ▷ Natural gas resources by category in India, end-2014 (bcm)

	Ultimately recoverable resources	Cumulative production	Remaining recoverable resources	Remaining % of URR	Proven reserves
Conventional onshore	1 570	280	1 280	82%	290
Shallow offshore	1 810	500	1 300	72%	340
Deep offshore	1 480	70	1 400	95%	770
Coalbed Methane	1 230	0	1 230	100%	20
Shale gas	2 720	0	2 720	100%	0
Total India	**8 810**	**850**	**7 930**	**90%**	**1 420**

Note: URR = ultimately recoverable resources.

Sources: IEA databases; BGR (2014); USGS (2012a, 2012b); OGJ (2013); BP (2015); Rystad Energy AS; India Ministry of Petroleum and Natural Gas.

Oil supply

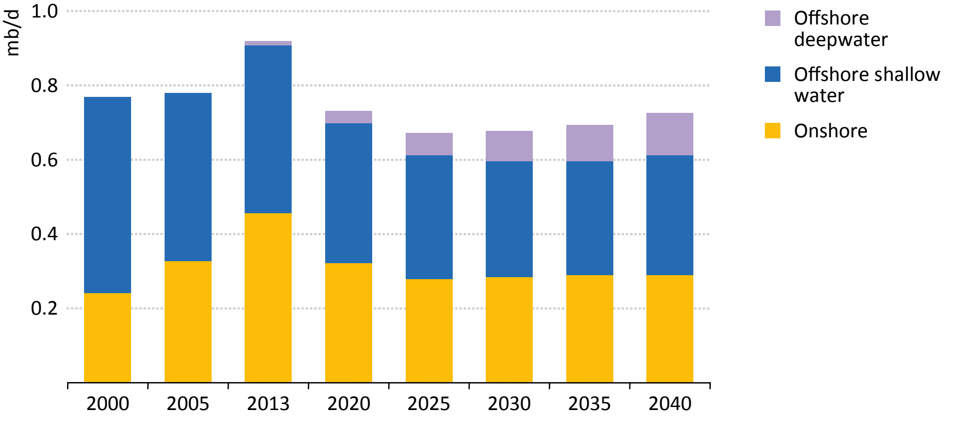
Oil production in India today comes primarily from three onshore states (Gujarat, Assam and Rajasthan, which account for more than 95% of onshore output) and from the aged Mumbai High field offshore. Output from the mature centres of oil production in Gujarat and Assam has been relatively stable for the last few years, with extensive field maintenance and the deployment of enhanced oil recovery (EOR) techniques to make the most of existing reservoirs. Production in Rajasthan has grown substantially in recent years, from close to zero as recently as 2008 to 170 kb/d in 2013, amounting to almost a quarter of national production, mainly as a result of the Mangala field being developed by Cairn India (despite the relative youth of the field, Cairn is already contemplating EOR techniques to assist with recovery of the waxy crude resource). Offshore production is concentrated in the Mumbai High field, south of Gujarat state, in shallow waters. This field, operated by India's majority state-owned Oil and Natural Gas Corporation (ONGC), has been in production since the mid-1970s and in decline since the late 1980s

In the New Policies Scenario, India's oil production falls in the medium term and then remains at around 700 thousand barrels per day (kb/d) throughout the period to 2040 (Figure 3.10). The boost to output due to the discoveries in Rajasthan subsides by 2020 and, although additional onshore discoveries of the magnitude seen in Rajasthan are not excluded, neither these nor the envisaged development of new reserves from the offshore basins are sufficient in the *Outlook* to outweigh the effects of declining production from existing fields. Limited domestic prospects, against a backdrop of continuously increasing oil demand, help to explain why the main Indian companies are also seeking investment opportunities abroad (Box 3.2).

Interest in the long-planned NELP X licensing round (the tenth round under the New Exploration Licensing Policy, now scheduled for 2016) will be an important indicator of

India's prospects. Licensing arrangements for the upstream have been modified over time to encourage private oil companies to participate in the development of India's resources, but success has been constrained by the limited size and quality of the resource base and the complex business environment. To date, within the 254 blocks awarded since the inception of the NELP, 128 discoveries have been made but only 11 fields have been developed and put into production. Foreign companies have entered the market, winning 40 of the 254 NELP blocks, but many of these blocks – including those held by Eni, Gazprom, Santos, Petrobras and BHP – were subsequently relinquished. BP and Cairn Energy are the main international operators that remain.

Figure 3.10 ▷ Oil production by source in India in the New Policies Scenario



Plans for the NELP X round include more than 166 000 km² of previously unavailable acreage, more than 80% of which will be in offshore regions. Some important innovations, due to be introduced in NELP X, are to be tested in a pending auction, announced in September 2015, of 69 marginal fields previously held by ONGC and Oil India Limited (OIL), but not developed because of their location, the size or complexity of the reserves or high development costs. The new terms will allow a license holder to produce any oil and gas, conventional or unconventional, found in the field (previously it was possible to produce only the hydrocarbon stream for which a license was granted). A second change is the introduction of revenue sharing contracts, instead of production sharing arrangements. The main feature of the revenue sharing approach is that, instead of the operator initially recovering costs and then sharing revenues from subsequent production with the government, the government would be entitled to a share of gross revenue from oil and gas sales from the start. Revenue sharing contracts are, in principle, potentially more straightforward to administer and their introduction could prevent some of the disputes over cost accounting that have burdened previous projects. But it remains to be seen whether the balance of risk and reward will be sufficient to attract new investors in the upstream, especially for acreage that requires exploration.

Box 3.2 ▷ Looking abroad: Indian overseas oil and gas investment

India has long been conscious of the value of overseas investment to domestic energy security: this was the spur already in 1965 for the formation of ONGC Videsh, the international arm of India's Oil and Natural Gas Corporation. We estimate that, as of 2014, the overseas production entitlement of Indian companies operating abroad had risen to around 140 kb/d of oil and 6.1 bcm of gas, and that Indian oil and gas companies invested some $3.5 billion outside their home country in 2014. Among the producing assets held abroad by Indian companies are significant stakes in Russia (in Sakhalin-1 and, more recently, in the large East Siberian Vankor field), Venezuela, Brazil, Myanmar, Azerbaijan, Sudan and South Sudan, as well as a share in one of Mozambique's major new offshore gas discoveries and unconventional assets in the United States and Canada.

India's companies have been noticeably less acquisitive abroad than those from China, whose estimated overseas oil entitlement is already around the 2.2 mb/d mark. But, in any case, neither country has a realistic prospect that acquired overseas assets could cover more than a fraction of their future import needs (and in the case of oil, at least, there is no reason to think that their respective overseas production is earmarked as a matter of course for the domestic market). The motivations and benefits are typically broader: they allow companies to diversify portfolios and risks, to develop integrated supply chains (especially in the case of natural gas) and secure access to technical knowledge and expertise (for example in deepwater plays or shale gas) that can be applied in the home market.

Oil market and refining

Indian refining capacity additions over the last decade have outpaced domestic demand growth and turned the country into a net exporter of refined products. However, staying ahead of domestic oil product demand that grows by 6 mb/d to 2040 represents a stern challenge for the Indian refining sector (Table 3.4). Gasoline and diesel consumption increase especially quickly, reflecting demand from both personal mobility and road freight. Total kerosene use, unusually, declines by 1% annually, as growth in aviation fuel demand is more than offset by the almost total elimination of kerosene demand from cooking. By 2040, India is set to become the world's largest liquefied petroleum gas (LPG)-consuming market but, in contrast to other major LPG consumers such as the United States, Middle East and China, most of Indian LPG demand comes from the residential sector, for use as a cooking fuel. India's petrochemicals sector is projected to consume imported ethane along with naphtha from domestic refineries.

Over the period to 2040, a further 3.4 mb/d of refinery capacity expansion in India to 2040 (third after China and the Middle East) and very high utilisation rates push refinery runs higher by 3.1 mb/d to reach 7.6 mb/d by 2040 (Table 3.5). Once majority state-owned Indian Oil Corporation's 300 kb/d Paradip refinery comes online at the end of 2015, there is a pause in anticipated large-scale capacity additions as only two other, smaller, projects are expected to be completed before the 2020s. Refinery expansion continues thereafter, but is ultimately held back in our projections by new refineries in the Middle East, India's close neighbour and biggest crude supplier, which provide a major challenge to Indian refiners in increasingly competitive product export markets. In the New Policies Scenario, the sheer size of India's demand growth and lower domestic crude oil output mean that Indian refinery output is increasingly drawn into the domestic market, and refinery capacity eventually falls behind domestic demand.

Table 3.4 ▷ Oil product demand in India in the New Policies Scenario (mb/d)

	2014	2020	2030	2040
Ethane	-	0.1	0.1	0.2
LPG	0.5	0.7	1.1	1.4
Naphtha	0.3	0.4	0.5	0.5
Motor gasoline	0.4	0.6	1.0	1.9
Kerosene	0.2	0.1	0.1	0.0
Diesel	1.4	1.8	2.6	3.5
Fuel oil	0.1	0.2	0.2	0.3
Other products	0.8	1.0	1.4	1.9
Total oil product demand	**3.8**	**4.8**	**7.0**	**9.8**

Table 3.5 ▷ Oil balance in India in the New Policies Scenario (mb/d)

	2014	2020	2030	2040
Oil demand	3.8	4.8	7.0	9.8
of which fractionation products*	0.5	0.8	1.2	1.6
Refinery products demand	3.2	4.1	5.8	8.2
Refining crude intake (refinery runs)	4.5	4.9	5.8	7.6
Domestic crude availability	0.8	0.6	0.4	0.4
Crude balance	-3.7	-4.3	-5.4	-7.2
Refined products balance	1.3	0.6	-0.2	-0.9
Fractionation products balance (LPG)	-0.3	-0.5	-0.9	-1.1

* Fractionation products are LPG and ethane, as well as the portion of naphtha/natural gasoline that is produced during gas fractionation.

Crude oil imports and product trade

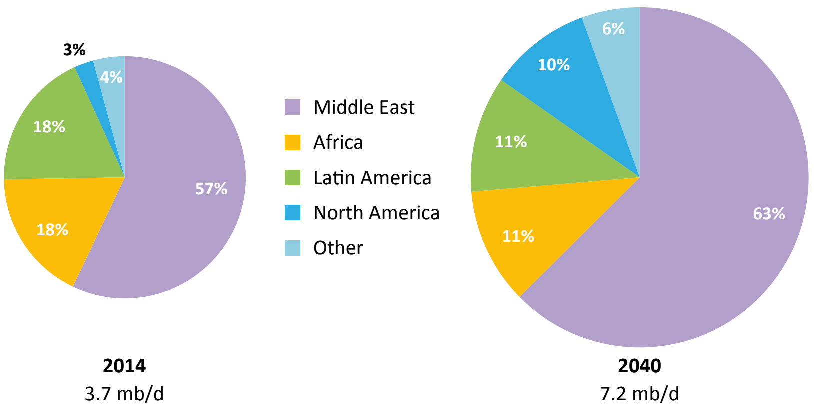
Our projections in the New Policies Scenario leave India with the need to import 7.2 mb/d of crude oil by 2040, up from 3.7 mb/d in 2014[5], which makes India the world's second-largest importer, behind China, but ahead of both the European Union and the United States. At the same time, India has the highest import dependency among the regions

5. Data from the Ministry of Petroleum and Natural Gas show a figure of 3.8 mb/d for crude imports in fiscal year 2014/2015. The number provided here is for calendar year 2014.

mentioned above, with over 90% of oil demand covered by imports in 2040, up from 70% in 2014. India's growing reliance on oil and gas imports carries with it a large bill. The value of India's net oil and gas imports grows from $110 billion in 2014 to more than $300 billion in 2030 and $480 billion in 2040 (of which gas accounts for some 10-15%). This represents a sizeable share of India's overall GDP – 5.3% in 2014 and 4.6% in 2040.

India currently sources some 57% of its crude imports from the Middle East, a share that is set to rise in our projections to 63% by 2040 (Figure 3.11). With new refining capacity is capable of running on very heavy crudes, India is also a potential market for Canadian bitumen, once the export infrastructure is put in place in Canada. Africa and Latin America increase their exports to India, but their market share decreases. Russia is not expected to provide a significant share of India's imports, beyond a recently announced long-term deal with private refiner Essar (for 0.2 mb/d), as logistics imply that Europe and northeast Asia remain the preferred markets for Russian crude exports.

Figure 3.11 ▷ Crude oil imports by origin in India in the New Policies Scenario



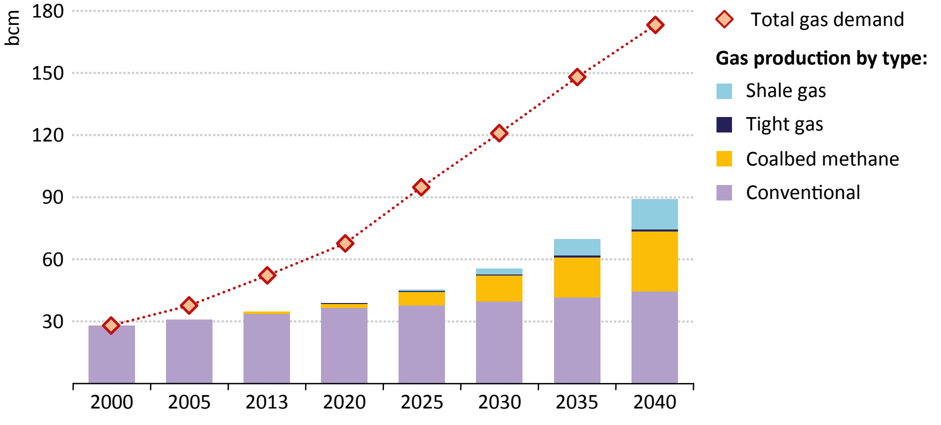
India imports a total of around 2.3 mb/d in oil products by 2040, but only half of this is refinery products, such as diesel and gasoline. The other half consists of almost 1 mb/d of LPG, with India becoming the world's largest LPG import market as a result. The Middle East is likely to provide the bulk of India's product imports, but it is possible that Indian consumers will source some products from further away – from European or North American refiners, reversing the east-to-west product trade flows that dominated the early 21st century.

Natural gas

In the New Policies Scenario, India's natural gas production increases from 35 bcm in 2013 to nearly 90 bcm in 2040, but this still leaves a sizeable gap of around 80 bcm that needs to be met by imported gas. Conventional gas production is dominated today by the ageing Vasai field on India's western coastal shelf: this field continue to attract investment by the operator, ONGC, which has long experience in optimising performance from mature fields.

Onshore conventional production consists of many small projects, only a handful of which contribute more than 5% of total onshore supply. There is potential for new gas discoveries onshore, considering the extent of unexplored acreage, but the larger potential lies offshore, with the deepwater Krishna-Godavari basin the centre of activity since the initial discovery by Reliance, India's largest private sector corporation, at the KG-D6 block (since followed by large discoveries in neighbouring blocks by Reliance and ONGC). The discoveries are in water depths of between 700 and 1 700 metres, and the wells are technically challenging, giving rise to a relatively high development costs. The KG-D6 project itself has also suffered from well performance issues, including higher than expected water production and sand entry, resulting in high decline rates.

Figure 3.12 ▷ Natural gas production in India in the New Policies Scenario



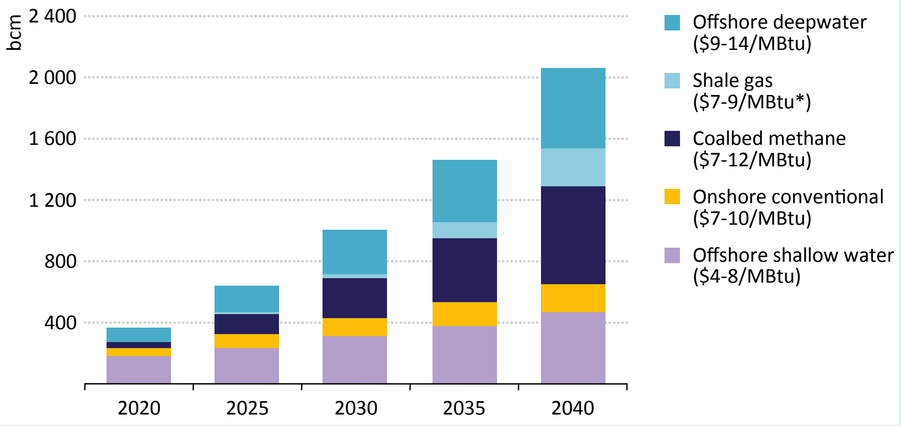
With the contribution from conventional onshore fields set to stagnate, the opportunities for substantial growth are first in the offshore basins, followed by onshore coalbed methane (CBM), which we assume to increase in the 2020s, and the possibility of shale gas output later in the projection period. Although resources are large, all of these sources of gas face substantial uncertainties: the disappointing production performance of Reliance's KG-D6 block has tempered expectations for offshore development. CBM projects have gotten off to a reasonable start, but development costs are still high. The shale gas resource is understood to be large, but appraisal is at a very early stage and large-scale production could run into significant problems over land use, water availability and acceptance by local communities.

Looming over all of these projections is the key question of whether the price available to domestic gas producers will be sufficient to incentivise the investment required. Our analysis of India's gas supply costs suggests that most new commercial gas developments are marginal in the price environment prevailing in the second-half of 2015: the new gas pricing formula put in place in 2014 initially established a price for domestic producers of around $5.6 per million British thermal units (MBtu), but subsequent six-monthly revisions brought this down to around $4/MBtu, because of falls in the reference prices to which it is linked (Box 3.3).[6]

Box 3.3 ▹ Finding a natural gas price that is right for India

India provides a vivid illustration of a difficulty faced by many gas import-dependent economies: how to find a pricing mechanism which produces a gas price that is acceptable to gas-consuming sectors, but is also sufficient to attract new investments in supply. There is no structure yet in place, such as a domestic trading hub, to determine the market value of gas in India, so the long-debated solution was to pick a basket of international prices to generate a reference price, although any such choice runs the risk of being out of step with the actual dynamics of the Indian gas market (OIES, 2015).

Figure 3.13 ▹ Gas resources developed in India in the New Policies Scenario



* India's shale gas resources have not been developed in quantities sufficient to estimate a supply cost. We have substituted an estimate for shale gas costs outside North America, based on *WEO-2013* (IEA, 2013).

Notes: A cumulative 2 050 bcm of new resource development is needed to deliver the 1 400 bcm of domestic gas output in the New Policies Scenario (many of the fields developed would also continue to produce beyond 2040). Costs vary significantly for each resource type: the cost figures shown here are representative of projects projected to come online through 2040.

Sources: IEA analysis based on IEA databases and Rystad Energy AS.

Based on the new formula and our international price trajectories for the different reference prices, the gas price available to India's domestic producers should recover from today's levels of around $4/MBtu to reach around $7/MBtu in 2025 and close to $9 MBtu by 2040. However, prices at these levels would not generate sufficient investment to meet our production outlook: we estimate that India needs to develop

6. The formula, which applies to the bulk of domestically produced gas, is linked to a weighted average of a set of international energy prices, including the US Henry Hub, UK National Balancing Point, the Alberta Reference Price and the Russian domestic gas price.

some 2 000 bcm of new gas resources over the period to 2040 in the New Policies Scenario (Figure 3.13). The related investment in exploration and development needs to be made well in advance of actual production and, in our judgement, some of the gas needed as early as the 2020s would require a higher price than that implied by the existing formula, or a premium attached to it.[7]

A higher gas price is not the only variable that affects the prospects for investment. The situation could also be altered by a change in the fiscal terms for upstream activity, or a reduction in the perception of risk associated with investment in India. Unconventional gas could also fundamentally change India's supply cost curve, if coalbed methane or shale could be brought on at an average cost of $7/MBtu or less. But the challenges are significant, especially given the intensity of drilling that would be required to bring down costs to these levels.

India has large coalbed methane resources and policies in place to support their development, although this has yet to result in a significant volume of gas output: production started in 2007 and stood at 0.2 bcm in 2013, with seven more blocks expected to start production in the near term. The profitable wells are typically shallow and do not require large-scale hydraulic fracturing. Much of the resource, however, lies in more complex environments requiring larger investment. Thirty-three blocks, covering almost two-thirds of the 26 000 km^2 areas available for coalbed exploitation, have been awarded to operators since 2001, but delays in the development phase have been common, arising from a complex permitting process and uncertainties over the gas price environment. Based on the size of the resource and India's need for gas, we do anticipate a rise in CBM production starting in the 2020s, with output reaching 28 bcm by 2040.

Shale gas is an important variable in India's gas future. Shale gas potential has been identified in six basins: Cambay, Assam-Arakan, Gondwana, Krishna-Godavari, Cauvery and the Indo-Gangetic plain and the resource size is understood to be large (although estimates vary widely), but activity has barely started – making the likely supply cost difficult to determine. A shale policy issued in October 2013 assigned the rights to exploit shale gas to the national oil companies, but this approach is likely to open up under the NELP X licensing round, which would confer rights to develop all hydrocarbon resources within a given block, both conventional and unconventional. To date, ONGC has drilled several shale research wells in the Gondwana and Cambay basins, but no commercial shale production exists today. In the longer term, water use is a key issue for the shale outlook in India, given the likelihood of water stress and the sensitivity of being seen to compete with agriculture use for a scarce resource. A limited volume of shale gas supply is included in our projections, starting after 2025 and reaching about 15 bcm per year by 2040.

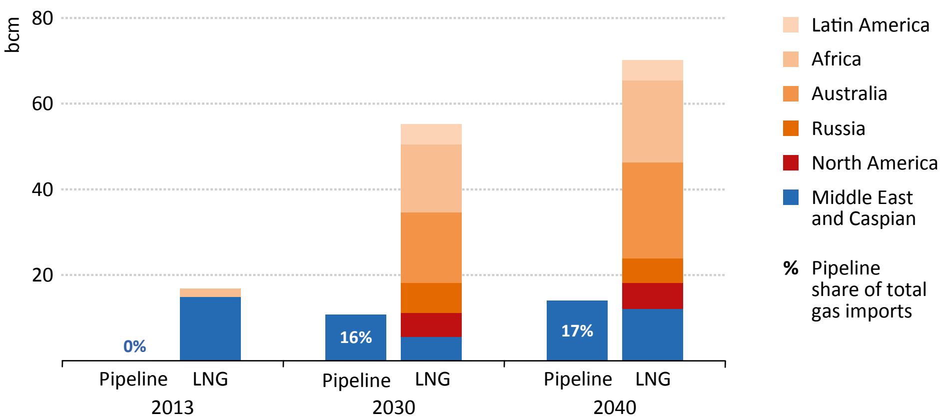
7. The government has envisaged that new gas discoveries in deepwater or with challenging reservoirs (high-temperature or high-pressure fields) will be given a premium over and above the approved price, although the details have yet to be approved. In the New Policies Scenario, we assume that the current pricing arrangements are successfully reformed in order to provide additional stimulus for upstream investment.

Sub-sea gas hydrates have been identified in large quantities within India's territorial waters and have at least a potential role in supplying energy in the future. India's Natural Gas Hydrate Programme is a consortium of the national upstream companies and research institutions, which has run several expeditions to map and sample prospective sites off India's eastern shore. Although the resource could be vast, high costs and uncertainties over commerciality preclude any inclusion of gas hydrate production in our projections.

LNG and pipeline imports

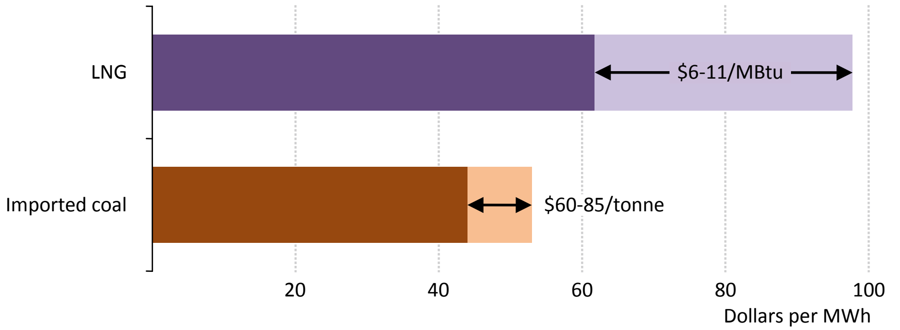
With domestic production falling short of the country's needs, India is set to import increasing volumes of natural gas, primarily in the form of liquefied natural gas (LNG) (helped by a period of lower LNG prices over the medium term) but also, potentially, via pipeline. Turkmenistan and Iran are the main prospective pipeline suppliers, although, in both cases, the prospects and timing are clouded by political uncertainties. In our projections, gas imports rise to over 80 bcm in 2040, with around 85% of the total being met by LNG and the remainder by pipeline (Figure 3.14).

Figure 3.14 ▷ Natural gas imports in India in the New Policies Scenario



The main uncertainty for imported natural gas relates to price and how and where this gas can find a niche in the Indian domestic market. India is reasonably well placed for LNG supply, because of its proximity to the Middle East and to prospective exports from East Africa; but this is, nonetheless, a relatively costly source of energy for many domestic users. In the power sector, for example, LNG (even at $6/MBtu) is too expensive to compete with imported coal as a fuel for baseload or most mid-merit electricity demand (Figure 3.15), leaving gas with only a limited role as a way to balance the system and meet peaks in power demand. (The circumstances in which gas could gain a more substantial foothold in power generation are examined in the Spotlight.) Increased reliance on LNG will also require adequate infrastructure: as of March 2015, India had four operational LNG terminals, giving it a total import capacity of 28 bcm, although other LNG terminals are in different stages of planning. Given that India's natural gas pipeline and storage network is limited, we anticipate that the focus for new LNG terminals will be the southern regions that are currently not served by major gas pipelines.

Figure 3.15 ▹ Levelised costs of gas-fired versus coal-fired power in India, 2020



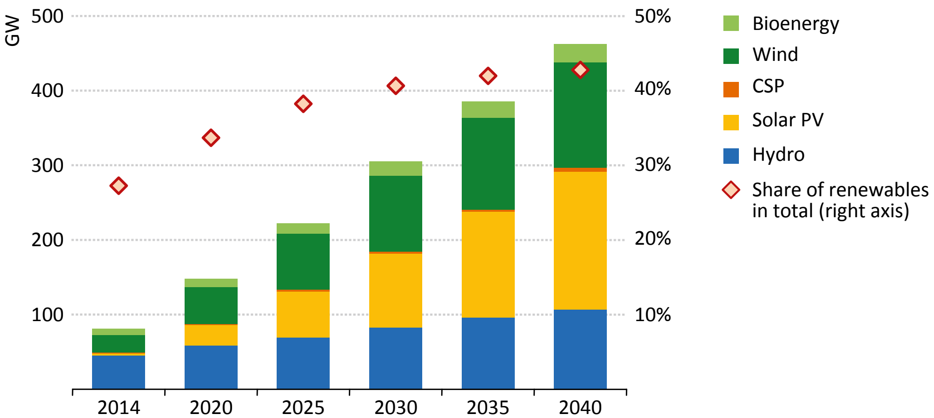
Notes: MWh = megawatt-hour. Calculation assumes efficiencies of 39% for new coal-fired generation and 53% for a gas-fired plant.

Plans to boost gas supply by pipeline centre on two proposed major pipelines, the Turkmenistan-Afghanistan-Pakistan-India pipeline (TAPI) and the Iran-Pakistan-India pipeline (IPI). Discussions on both have been going on for many years, but there are still substantial political and commercial obstacles; the security situation in Afghanistan and the relationship between India and Pakistan fall into the first category; open questions about pricing and financing into the second. In our view, these political uncertainties and the availability of relatively inexpensive LNG in the medium term rule out an early prospect of India receiving pipeline gas. Nonetheless, we see potential for one or both of these projects to be viable in the long term and project that gas imports to India start in the latter part of the 2020s. In either case, Turkmenistan's large resources may have an important role to play, either directly as supplier in the case of TAPI or indirectly in the case of IPI (with increased Turkmenistan exports to Iran meeting a part of northern Iranian demand and freeing up Iranian gas in the south, where most of Iran's gas is produced, for export).

Renewable energy

The abundance of renewable energy resources across India, allied with declining costs for their exploitation in some cases and clear synergies with the country's development and energy security goals, has created a fertile environment for their expansion. The overall picture is skewed by the continued large-scale use of solid biomass as a traditional cooking fuel. Looking forward, the gradual retreat from this form of consumption actually serves to drag down the share of non-fossil fuels in the overall energy mix, but energy from all other renewable sources grows strongly, particularly in the power sector, where renewables account for half of all the new capacity brought online over the period to 2040, increasing their share of capacity in the power mix from 28% to more than 40% (Figure 3.16).

Figure 3.16 ▷ Renewables-based power generation capacity in India in the New Policies Scenario



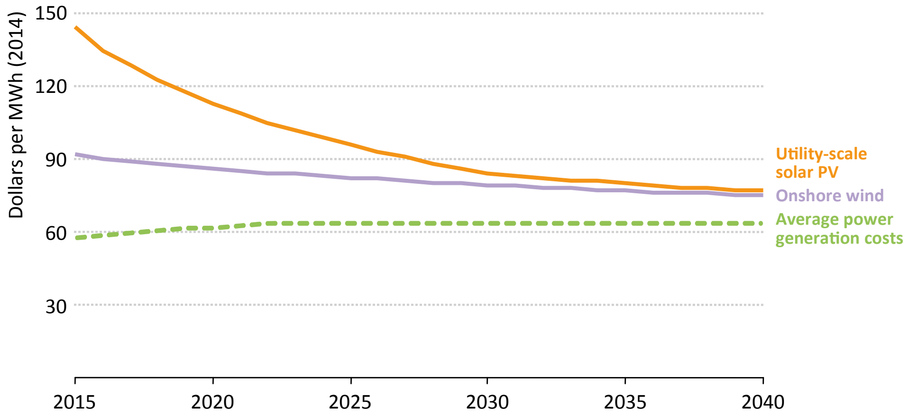
Note: GW = gigawatts.

India's renewable energy resources, unlike those of fossil fuels, are spread much more evenly across the country, although there are still some strong regional variations – particularly for hydropower. But, alongside questions of resources, the pace at which renewables develop in India is also subject to different doses of policies and economics, which vary state-by-state as well as technology-by-technology. The economic drivers are becoming stronger as technology costs fall, particularly for wind and solar power, but are not yet strong enough to justify investment without some form of subsidy. The expansion of hydropower relies strongly on concessional long-term financing and a readiness to expedite the necessary approvals. There is no single system of official support for renewables in India, rather an intricate patchwork of different national and state-level initiatives that encompasses feed-in tariffs, purchase obligations, bundling renewable with thermal output, accelerated depreciation schemes and a range of interventions that lower the cost of financing.

Costs

Hydropower, where it can be built, is established as a relatively competitive contributor to the Indian power mix, although a trend of decreasing output per unit of installed capacity is pushing up the average cost. In the case of wind and solar power, although they still require subsidies to incentivise investment, the cost trajectory is moving in the opposite direction. For solar, recent trends bode well for the future: since 2010, the average levelised cost of electricity generated by utility-scale solar in India has fallen by around half, largely reflecting a decline in the investment costs for solar cells. Albeit at a slowing pace, costs are expected to continue to decline throughout the projection period, falling by over 45% to 2040, by which time the levelised cost of electricity will be similar to that of wind power and coming close to full convergence with the average cost of power generation in the Indian system (Figure 3.17).

Figure 3.17 ▷ Levelised cost of electricity from wind, solar PV and the average cost of power output in India in the New Policies Scenario



Notes: MWh = megawatt-hour. Onshore wind and utility-scale solar PV indicate the average cost of capacity deployed. Average power generation costs = average power generation costs for all technologies.

The cost of onshore wind power follows a different trajectory. While these costs are significantly lower than solar PV today, they do not see a material decline, falling by only 18% to 2040. This reflects higher capital costs for the taller towers with larger turbine blades that are increasingly deployed to maintain efficiency factors after the best wind sites are occupied, as well as the more limited scope which exists for technological improvements and local learning to bring down costs, as wind turbine technology is standardised globally and much of the potential for efficiency improvements already exploited. The increase in the average cost of generation across the system as a whole nonetheless means that the cost of onshore wind goes from being around 60% higher than the average to being much closer to par.

These sorts of generic cost calculations do not capture the range of considerations that apply when deciding on technologies for power generation; these include expected revenues, environmental concerns, as well as a plethora of other factors, such as the diversity of the generation mix and the local availability of resources. In addition, the significantly different generation profiles (and therefore economics) of fossil fuel or nuclear baseload capacity means that comparing their levelised cost of electricity with those of solar and renewables, which are inherently variable, is an exercise with considerable limitations.[8]

Solar power

India has substantial solar potential, estimated by India's National Institute of Solar Energy at around 750 gigawatts (GW) (based on the assumption that 3% of wasteland in each state can be used for solar power projects, plus an assessment of the potential for rooftop solar).

8. See Chapter 8 of the *World Energy Outlook 2015* (IEA, 2015) for a full description of power generation costs.

This represents almost three-times India's total installed power capacity today. The solar resource is strongest in the north and northwest of the country (Rajasthan, Jammu and Kashmir), but it is also considerable in a number of other states, including Maharashtra, Madhya Pradesh, and Andhra Pradesh. Installed capacity has been growing quickly. Utility-scale solar photovoltaic (PV) projects have made the fastest in-roads, with about 4 GW of capacity in place as of mid-2015 (up from 3 GW in 2014). Rooftop solar installations have been slower to take off, with around 450 megawatts (MW) of capacity installed as of 2014. Concentrating solar power (CSP) has only just started to gain ground, with around 200 MW in operation.

Solar power is at the heart of India's push towards low-carbon energy sources. The overall national target is to reach 100 GW of installed capacity by 2022, a huge task given the starting point. This total is split between 60 GW of utility-scale projects (both solar PV and CSP), including a series of large solar parks, with capacity generally above 500 MW each, and a further 40 GW of rooftop solar applications for commercial users and households, together with some small-scale schemes and off-grid capacity. A range of national and state-level initiatives have been announced in support of these objectives. Since electricity is a shared responsibility between federal and state authorities, the political commitment of individual states to solar power is critical to the prospects for growth (Box 3.4).

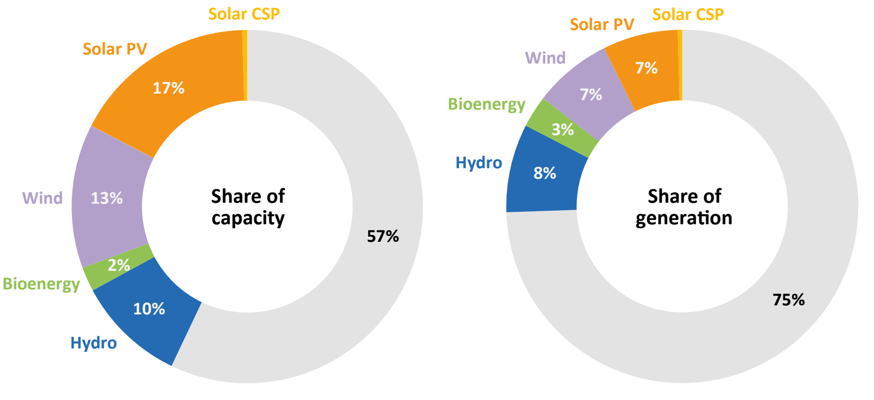
Box 3.4 ▷ Gujarat's shining example

The state of Gujarat has 1 GW of installed solar capacity, accounting for more than a quarter of India's total. All but 26 MW of this capacity was built on the basis of policies determined by the state itself. A turning point came in 2009, when the state government announced a new policy on solar power aiming to attract capital by removing a number of impediments that were stifling investment. It introduced exemptions for electricity duties, streamlined the land acquisition process, guaranteed evacuation of power by the Gujarat Energy Transmission Corporation, ensured that no cross-subsidy charges were levied for access within the state and guaranteed tariffs for 25 years. The 500 MW Charanka solar park in Patan – one of the largest in the world – is a notable outcome.

Other states have drawn on lessons from the success achieved in Gujarat. Rajasthan adopted its Solar Policy in 2011, containing a number of the elements of the Guajarat approach, and has subsequently updated it to further ease land acquisition, including by allowing projects to use agricultural land without first needing to register a land-use change. In June 2015, the state government of Rajasthan signed a joint venture agreement with Adani Power (an Indian private company) to invest $9 billion in a 10 GW solar park.

India's solar targets are not met within the envisaged timescale in the New Policies Scenario (see Chapter 2, Spotlight), but the solar sector does witness dramatic growth – faster than any other source of generation. Installed capacity rises to 29 GW in 2020 and 188 GW by 2040, making India the second-largest solar market in the world, after China. This boosts the share of solar power in India's total power capacity to 17% in 2040 from around 1% today, although it accounts for a smaller share (7%) of generation in 2040 (Figure 3.18). Most new capacity is utility-scale, mostly solar PV, with a much smaller share of CSP. A number of challenges confront solar deployment, including the difficulty of enforcing purchase obligations on the local distribution utilities, the ability of the grid to absorb the additional production, availability of financing and land acquisition issues (even where states have expressed strong interest in the initiative to create solar parks, in practice it is proving difficult in many cases to identify and acquire suitable land).

Figure 3.18 ▷ Share of renewable energy capacity and generation in India, 2040



One solution to the problem of land acquisition for utility-scale solar development is to go, instead, for rooftop solar. Although this has been slow to take off so far, it is an area of potentially very rapid growth, with considerable upside over our projected 83 GW of deployment (particularly if the reliability of grid-based supply does not improve). Most of the early adopters of rooftop solar (around two-thirds thus far) have been commercial and industrial consumers, with one attraction being to hedge against interruptions to supply and to displace daytime reliance on diesel-fired generators. As conventional tariffs rise, solar generation costs decline and there is greater regulatory clarity over issues like net metering (i.e. the conditions under which generated power can be offset against utility bills, or sold to the grid) as well as easier access to innovative business models and financing options (to overcome the high upfront cost), so more and more customers could be encouraged to adopt rooftop solar PV systems.

SPOTLIGHT

Can India bypass coal for solar- and wind-based electrification?

The cost competitiveness and investment outlook for wind and solar PV have improved dramatically in recent years and our projections suggest that these sources are set to play a major role in expanding electricity supply in India. But these technological gains and cost reductions have also nurtured the idea in some quarters that India could see a more dramatic break with the past: that India could now opt for a low-carbon electrification path that not only reduces coal use but also bypasses the need for new coal-fired capacity. How feasible is such a pathway for India?

Our assessment is that India is unlikely to reach a situation in which the case for investment in new coal-fired capacity disappears. There are a number of reasons, chief among which is the sheer scale of the electricity demand challenge. As underlined in Chapter 2, keeping pace with power consumption growth at 4.9% per year is already a stern challenge for India, even with all generation options on the table. Relying on a very rapid pace of wind and solar deployment to meet a much larger share of rising demand could also run into significant supply-side challenges, stemming – in the early years at least – from disinclination in India to rely too heavily on imported solar panels and wind turbines.

In practice, while large-scale wind power and solar deployment will have a significant impact on the amount of electricity thermal plants are required to generate, thereby slowing the growth of coal use, the potential impact on the need for actual coal (or gas) capacity is much smaller. This is because of the well-known issue of variability in wind and solar output, an especially pertinent consideration in India, given the relative weakness of the transmission network, the evening peak in power demand and the measurable seasonality in solar and wind output that comes with the monsoon. Managing variability is far from an insuperable problem, but the various options that improve system flexibility and so limit the need for thermal capacity (strengthening the grid, demand-side management and investment in electricity storage) all have their own regulatory or cost challenges.

While India is unlikely to eliminate the need to build conventional power generation capacity, the increasing scale and cost effectiveness of renewables deployment nonetheless have implications for India's choice of thermal power plants. The split varies from country-to-country, but a typical division of labour in a power system between coal and gas is that coal takes care of baseload operation, operating at relatively high capacity factors, while gas more flexibly follows the daily load curve, helping to meet demand peaks. India has a very coal-heavy variant on this theme: both fuels have had issues with availability of domestic supply, but – with imported LNG typically available only in an expensive $10-14/MBtu range from 2012-2014 – the business case for coal, even for mid-merit plants, was superior, leaving gas with only a small peaking role.

The fall in the oil price and the increasing availability of new LNG supplies is, though, now suggesting a much more favourable medium term LNG price environment for buyers in India. The parallel improvement in the cost efficiency of both gas and renewables is opening up the possibility for India of a large-scale electrification pathway based on solar-plus-wind-plus-gas, which could challenge coal's predominance as a provider of baseload generation. Such a switch to gas is not the way that our New Policies Scenario plays out, but it is feasible, if there is a confluence of four factors:

- **A reform to domestic coal pricing in India.** As things stand, domestic production is sold to power generators at prices that are well below import prices. This artificially increases the attractiveness of coal, making it very hard to out-compete. Bringing the coal price up to import parity, either through deregulation or a rise in the administered price (collecting the associated rents via taxation), would help to swing the choice in favour of higher efficiency coal-fired generation technology and help the investment case for gas. Carbon pricing would reinforce this effect. But the elimination of subsidies would be a first step.
- **Avoiding a strong rebound in LNG prices.** This is not an area in which Indian energy policy has great sway (although policy-makers could do much to create conditions for a more competitive traded gas market at home, and Indian companies are increasingly prominent investors in LNG projects abroad, notably in East Africa). But sustained LNG prices in single digits would considerably ease the path for gas in the power generation mix.
- **Achieving cost-efficient investment in renewables.** The average investment cost of the renewable portfolio is a key component of the competitiveness of the "renewables-plus-gas" option. India has high potential for wind and solar, but international experience suggests that the regulatory and licensing environment, grid connection and local content rules, and the operation of local equipment and service markets have a major impact on investment costs.
- **Preferential costs of capital for renewables.** Even if these first three conditions are met, we estimate that the total costs of baseload coal remain difficult to beat without government support. For example, the "renewables-plus-gas" option becomes more attractive if there is a substantial difference in the cost of capital, favouring renewables. This is possible, but would require direct government intervention (see section on financing the power sector in Chapter 4). From India it requires a regulatory regime that creates sufficient security and predictability to enable lenders to lower their cost of capital, and efforts to unlock new sources of long-term finance, for example via domestic capital markets. From the international community, conscious that the carbon intensity of India's power generation is a critical barometer of the success or failure of global climate policy, it requires a framework to channel low-cost financing to low-carbon investment in India.

Wind power

Estimates of India's wind power potential vary greatly, depending on different assumptions of efficiency, hub heights, turbine size and land-use considerations. The most recent official estimates by the National Institute of Wind Energy, which take into consideration only land deemed suitable for wind turbine installations[9], put total onshore wind power potential with a hub height of 100 metres at 302 GW (National Institute for Wind Energy, 2015). The most promising sites are in the west and south, with around 90% of the potential in the states of Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Karnataka, Maharashtra and Gujarat. Wind power generation is projected to increase strongly, with installed capacity rising from 23 GW to 142 GW in 2040. Further development is not constrained by lack of wind resources, but by a number of challenges, ranging from land acquisition and approval processes, to agreements on an appropriate framework for power purchases by distribution utilities. Competition with solar is another factor limiting further growth in wind power: despite proliferating strongly, installed wind capacity grows at less than half the pace of solar PV, in part due to the narrowing gap in the cost of solar compared with wind (and its full convergence by the late 2020s), and the widespread nature of solar resources that makes it possible for large utility-scale solar projects to be built closer to demand centres. Offshore wind farms circumvent land acquisition issues, but their outlook is dampened by higher investment requirements and costs. Another way to overcome problems associated with land purchases is to build wind towers on existing farmland, allowing farmers to raise additional income from charges to the operators, without prejudicing their ability to farm the land.

Over the projection period, gradual exploitation of the best sites, both in terms of the wind conditions and proximity to the large demand centres, means that turbines are increasingly built away from the prime areas, and have to use larger towers and longer turbines, driving up the capital costs. This however results in an increase in the average capacity factors, from 18% to 24% (though this remains significantly below the world average, reflecting the conditions of the wind resources at the available sites). Beyond the well-known advantages of renewable energy for power generation, the large-scale development of wind power offers the potential to develop expertise and an industry that can deliver services internationally. There is already evidence of this, with Suzlon, an Indian company, now the world's fifth-largest wind turbine supplier, operating factories in the United States, China and India. International firms have also entered the Indian market, drawn by its size and a number of tax incentives, with General Electric setting up a plant in Pune where turbines can be manufactured.

9. This excludes protected areas, roads, railways, airports and land areas with an elevation over 1 500 metres and a slope of more than 20 degrees.

Hydropower

Although capacity has steadily increased, the contribution of hydropower to Indian power generation has been on a declining trend in recent decades, from close to 40% in 1980 to 12% in 2013. Hopes that this trend might be reversed rest on the sizeable remaining potential – India has used a little over a quarter of its economically feasible hydropower resource – as well as on the operational advantages of hydropower in balancing a power system which has an increasing share of wind and solar capacity. To tap into this potential, hydropower projects need to overcome a set of challenges common to many large infrastructure projects in India, notably extended timelines to procure all the necessary approvals, especially environmental permits, difficulties with land acquisition (both for the plant and for new transmission lines to evacuate the power), public opposition and obtaining long-term finance. In addition, there are issues specific to hydropower, notably the high levels of sediment in the rivers coming down from the Himalaya Mountains, which can reduce reservoir storage capacity and, if not removed, cause heavy damage to turbine blades and other steel structures in a hydropower plant. Last but not least, there is the uncertainty over the impacts on water flows of a changing climate.

Our projections in the New Policies Scenario are based on the assumption that the prospects for such large infrastructure projects gradually improve, as a result of government efforts to simplify permitting and authorisation procedures, as well as improvements in project planning and consultation (including better co-ordination to avoid water-sharing disputes between the different states affected by projects along the various river systems). This helps to expedite both the 14 GW of projects that are at various stages of construction, as well as new projects that come into operation later in the projection period (CEA, 2014). The result is a rise in installed capacity for large hydropower from 42 GW in 2014 to just under 100 GW in 2040, with most of the increase taking place in the latter part of the projection period in the northern and northeast regions, where India's remaining hydro potential is concentrated. Small hydropower, projects up to 10 MW[10], also plays a growing role, particularly in meeting the power requirements of remote, mountainous areas. Their capacity increases from 2.8 GW to over 10 GW by 2040. Although total output rises to around 330 terawatt-hours (TWh) in 2040 (up from 142 TWh in 2013), hydropower's share of the generation mix continues its steady decline, falling from 12% in 2013 to 8% in 2040.

Another avenue for India to benefit from hydropower is through co-operation with neighbouring countries. Hydropower is becoming an important pillar in the relationship with Bhutan, with three projects of around 1.5 GW in total already developed with Indian assistance, a further ten projects in various stages of construction or preparation and plans to strengthen transmission lines to export surplus power to India. Similar arrangements are in place with Nepal, including the approval of projects with a combined capacity of 1.8 GW in 2014.

10. India's Ministry of New and Renewable Energy defines small hydro as plants with capacity of up to 25 MW, while only those with capacity under 10 MW are included in the definition used in the *World Energy Outlook*.

Water issues are very sensitive in India and lack of public acceptance of hydropower development has already been a major obstacle to projects moving ahead. The most difficult issue has been the resettlement of people affected by new projects, but public attitudes have also been adversely affected by the by floods in the Himalayan state of Uttarakhand in 2013, which prompted a major debate over whether intensive hydropower development in the region was to blame for the severity of the flooding. This episode underlined the importance not only of evaluating individual projects in depth, but also of taking a broader view on the development of river basins, assessing the linkages between projects and the cumulative social and environment impacts. In our projections, we anticipate an increasing focus on run-of-river projects; these avoid expansive reservoirs and can thereby ease the need for resettlement and so help to secure public acceptance. But these projects have little or no water storage (rarely more than the equivalent of a few hours' worth of generation), limiting their ability to be dispatched on a flexible basis. Their power output is often subject to significant seasonal variations.

Bioenergy

Bioenergy demand rises by around 11% over the projection period to 2040, a moderate increase that results in the share of bioenergy steadily shrinking in the Indian energy mix. Availability of supply is not the reason for this trend, except in the case of biofuels (Box 3.5). Data from the United Nations Food and Agriculture Organization (UNFAO, 2015) indicate that the total area covered by forests in India has actually increased in recent years, suggesting that – despite evidence of localised shortages in parts of the country, including the northeast – there is no overall scarcity of fuelwood for use by rural households as a traditional cooking fuel. This can limit the economic incentive for rural households to switch to alternative fuels, such as LPG where it is available, or to invest in more efficient biomass cookstoves.

Box 3.5 ▹ How much land can India spare for biofuels?[11]

India has set itself high blending targets for biofuels: to increase the share of bioethanol and biodiesel up to 20% (for gasoline and diesel, respectively) by the end of the Fifth Plan (2017).[12] In 2013, the actual level of blending was below 1%, with bioethanol making more ground than biodiesel but both facing constraints on supply. A key uncertainty in projecting future supply is the availability of land. Overall, some 57% of India's land mass is available for agriculture, with an additional 3% of pasture, 8% of woodlands and the remainder being either forests or other areas hardly suitable for productive use (e.g. mountains, deserts, built-up areas). Biofuels can play a role in buttressing India's energy security, but their expanded cultivation could, at a certain point, compromise other critically important Indian policy objectives, notably food and water security or protection of forest areas.

11. This analysis was developed in collaboration with the Center of Applied Mathematics, Mines ParisTech.

12. The National Policy on Biofuels has an indicative target of 20% by the end of 2017. A minimum of 5% ethanol blending has been made mandatory in 20 states and 4 union territories.

The land area available for biofuels cultivation in the future depends on assumptions about agricultural productivity and about the share of land available for agriculture that has effective irrigation (currently, only around 35% of the total is irrigated). Even with an optimistic set of assumptions on these two variables to 2030 – a doubling in productivity and of the share of agricultural land with irrigation – we estimate that there is still not enough land left for biofuels cultivation to meet both the 20% targets.

Our calculation would leave around seven million hectares available for crops to produce biofuels, with different degrees of suitability for their cultivation. Based on the assumption that sugarcane and rice are the crops used for bioethanol and jatropha for biodiesel (the preferred crops identified in the Ethanol Blending Policy and the National Bio-Diesel Mission), this land could either produce 225 thousand barrels of oil equivalent per day (kboe/d) of bioethanol (plus around 75 kboe/d of bioethanol produced from molasses, a by-product of the conversion of sugar cane juice to sugar) or 105 kboe/d of biodiesel in 2030. The 300 kboe/d of bioethanol would represent around 30% of the projected demand for gasoline for road transport, while the 105 kboe/d of biodiesel would represent only 5% of projected demand for diesel (bioethanol is a more productive avenue than biodiesel, because of the higher energy yields of sugarcane). The choice of sugarcane, a water-intensive crop, carries the risk of exacerbating India's problems with water scarcity; but less water-intensive crops, such as wheat and rice, provide lower energy yields.

The development of advanced biofuels could change this picture, not least by avoiding potential conflicts with food security. But a lack of progress in commercialising these advanced biofuels around the world gives us reason to pause before anticipating a significant reduction in their costs or a rapid increase in their deployment. Although the potential in India is large, with ample agricultural residues available as feedstock, this is an area that still requires a major effort in terms of research and development. As things stand, the sensitivity of land-use issues in India and the vital importance of food and water security impose significant constraints on the outlook for biofuels. Although biofuels production is projected to increase in our *Outlook*, biofuels continue to occupy only a modest 3% overall share in the road transport fuel mix in 2040, with advanced biofuels accounting for around one-fifth of the biofuels produced.

For other predominantly rural but modern energy applications, such as power plants fired with bioenergy (e.g. bagasse-based cogeneration at sugar mills) or biomass gasifiers to produce biogas, there is, in principle, ample surplus biomass available (mainly from agricultural and forestry residues), although supply in practice depends on reliable systems for collection, transportation and storage. In our projections, power generation based on biomass rises by more than five-times to reach around 120 TWh in 2040, providing a valuable contribution to the reliability of rural electricity supply. But despite policy support for modern biomass technologies in India, the uptake of bioenergy-based supply is constrained by relatively high costs and by poor access to financing.

In urban areas, the ready availability of LPG as a cooking fuel means that consumption of solid biomass is low. This applies also to charcoal, which is hardly used in Indian towns and cities, relieving pressure on nearby woods and forests. One under-utilised option for urban energy supply is municipal waste – a natural product of the rise in India's cities but one that is becoming a major health and environmental hazard: it is estimated that only 20% of the total urban waste is treated, leaving the rest to be dumped untreated at open sites (Planning Commission, 2014). This is a largely unexploited resource, the use of which would not only generate electricity and biogas, but which also has the potential to bring co-benefits by reducing the area required for landfill, a major consideration in India's sprawling cities, and improving public health (although care would be needed to avoid toxic emissions from waste incineration). The Ministry of New and Renewable Energy has classified waste-to-energy as a renewable energy source and put in place subsidies and incentives to encourage projects, which are already underway in Hyderabad, Pune, Ghazipur and Delhi.

Nuclear power

India was one of the first countries to adopt nuclear power technology, with its first commercial reactor coming online in 1969. Its nuclear industry has developed by relying heavily on indigenous technologies, as a result of its status as a non-signatory to the Nuclear Non-Proliferation Treaty (which led to restrictions on the export of nuclear materials to India). However, following the India-US Civil Nuclear Agreement in 2008, the Nuclear Suppliers Group lifted the sanctions that had been in place since 1974, thereby opening the door for India to trade with foreign suppliers of nuclear fuel and technology.

India has a strong commitment to develop additional nuclear power as a way to meet its rising energy needs and enhance its energy security on a low-carbon basis. Its current target is to triple nuclear power capacity over the decade from 2014 (which would equate to capacity of 17.3 GW in 2024). It also has a longer term target for nuclear power to supply 25% of the nation's electricity by 2050. India ranks as the world's 13th largest country in terms of nuclear generation, with installed capacity of 5.8 GW in 2014 with 21 reactors at seven sites. It has a further six reactors, with a total capacity of around 4 GW, in various stages of construction.

India's domestic resources of uranium are limited compared with its current needs and future aspirations. These are estimated to include 129 000 tonnes of reasonably assured resources and a further 29 000 tonnes in the inferred category; or, in aggregate, around 2% of the world total (IAEA/OECD, 2014). However, these uranium resources are low grade and located in remote areas, meaning that imports represent a necessary and less expensive option. By alleviating shortages of reactor fuel, the 2008 agreement has enabled a substantial increase in the average load factor at India's nuclear power plants, from less than 50% in 2007 to over 80% in 2013. India also has the world's largest reserves of thorium, which is a potential alternative to uranium fuel in nuclear reactors. To take advantage of this rich resource base, and as it was not permitted to import uranium, India has become a leader in researching and developing thorium-based nuclear power. It plans to have a first pilot reactor in service by 2022 and commercial reactors deployed by around 2030, although many economic, technical and regulatory challenges first need to be overcome.

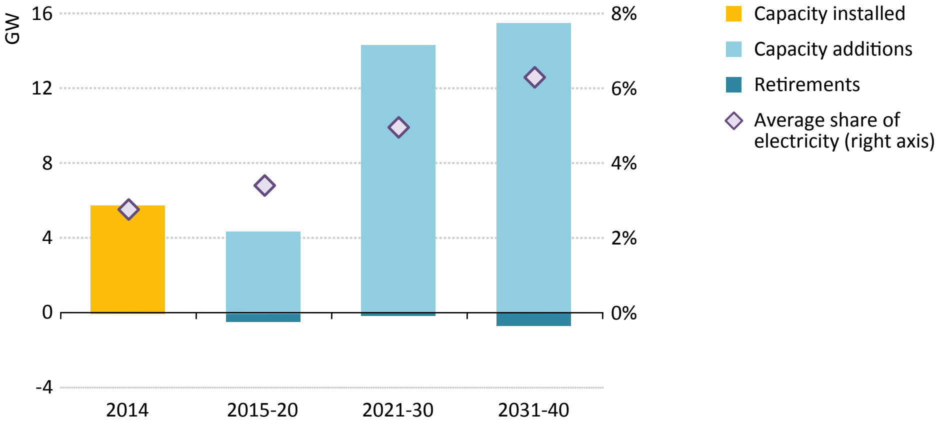
The 2008 agreement also meant that foreign suppliers of nuclear power plants can do business in India. However, many suppliers were unwilling to make investments, due to concerns that India's nuclear liability law held them directly liable in case of an accident: standard practice internationally is that liability rests with the plant operator (which in India would effectively mean the government, since the sole operator – Nuclear Power Corporation of India Limited – is government owned). In June 2015, India set up an insurance pool that provides cover to both operators and suppliers in the case of a nuclear accident. Time will tell whether this solution provides adequate reassurance to overcome a serious obstacle to future development of nuclear capacity in the country.

Economic considerations will also be a major determinant of the future of nuclear power in India, as in all countries pursuing the technology. A useful, though imperfect, means of assessing the lifetime economics of new power plants is to consider the costs of electricity generation, compiled on a levelised cost basis (IEA, 2014). In the New Policies Scenario, levelised costs for nuclear power plants coming online in India in 2030 average around $69 per megawatt-hour (MWh). This is lower than in many other parts of the world – for example they are $110/MWh in the European Union – primarily because the overnight costs of construction are lower in India. Based on these estimates, nuclear power appears to be an economically attractive option in India, particularly in parts of the country that are distant from coal reserves (not surprisingly, this is where the current fleet is concentrated). Nonetheless, building a nuclear power plant is a very capital-intensive undertaking, involving a large upfront investment: India's fiscal and current account deficit means that it will be very reliant on foreign capital for such investments. For foreign capital to be forthcoming, it will be necessary to ensure there is an attractive legal and regulatory framework in place. The recent progress that has been made to address issues surrounding the nuclear liability law is a positive development in this respect.

Public concerns could also exert a powerful influence on the prospects for nuclear power in India. Earlier debate in the country about nuclear power plants focussed on the displacement of communities and the adequacy of compensation if plants were built near them. But, since the accident at Fukushima Daiichi in Japan, these have been supplemented by more widespread concerns about plant safety and the risks of nuclear technology. Protesters have focussed on the Kudankulam Nuclear Power project, located on the coast in the southern state of Tamil Nadu, a region that was badly affected by the huge Indian Ocean tsunami in 2004. Confidence in regulatory frameworks and institutional capacity will, therefore, be key factors in securing broad public support to expand nuclear power in India.

In the New Policies Scenario, India's nuclear power capacity increases by a factor of nearly seven, from 5.8 GW in 2014 to almost 39 GW in 2040, having reached 9.7 GW in 2020 (Figure 3.19). On a worldwide basis, India sees the second most significant increase in installed nuclear capacity, after China. Reaching this level of capacity in 2040 implies a construction rate of 1.3 GW per year on average, which is significantly faster than the rate realised in the recent past and would need to be sustained over a long period. India's nuclear electricity generation increases from 34 TWh in 2013 to nearly 270 TWh in 2040, an average rate of growth of 7.9% per year (faster than growth in electricity supply as a whole), resulting in the nuclear share of total generation more than doubling from 3% to 7% over the period.

Figure 3.19 ▷ Nuclear capacity additions by time period in India in the New Policies Scenario



Implications of India's energy development

What would it mean to realise India's energy vision?

Highlights

- The energy system in India in the New Policies Scenario in 2040 is transformed in every respect from today: operating on a different scale; more diverse in terms of players, fuels and technologies; far more complex to manage; and requiring much larger inflows of capital. Developing such an integrated system in a cost-efficient way, and ensuring its reliable operation while mitigating environmental impacts, is a major challenge for policy at national and state levels. But the prize in terms of improved welfare and quality of life for India's population is enormous.

- Our projections show India moving to the centre of global energy affairs, accounting for 25% of the rise in global energy use to 2040, (more than any other country), and the largest absolute growth in both coal and oil consumption. India becomes a major player in renewable energy, with the second-largest solar market in the world. India's increasing reliance on imported energy has a profound effect on global energy investment and trade and – especially for oil – implications for India's energy security which need attention. Heavy reliance on coal leads to a large rise in India's energy-related CO_2 emissions, although, expressed on a per-capita basis, emissions remain some 20% below the world average in 2040.

- In an Indian Vision Case, we examine the implications of an accelerated realisation of key Indian policy targets, notably the "Make in India" campaign to promote manufacturing, and universal, round-the-clock electricity supply. Putting industry at the heart of India's growth model means a large rise in the energy needed to fuel development, at least ten-times more energy per unit of value added compared with growth led by the services sector. To avoid that this further exacerbates energy security and environmental strains requires a tireless emphasis on energy efficiency, both in end-uses and in the power sector, accelerated investment in wind, solar and other renewables, and the deployment of advanced emissions control technologies to reduce local air pollution and the damage that it causes to health.

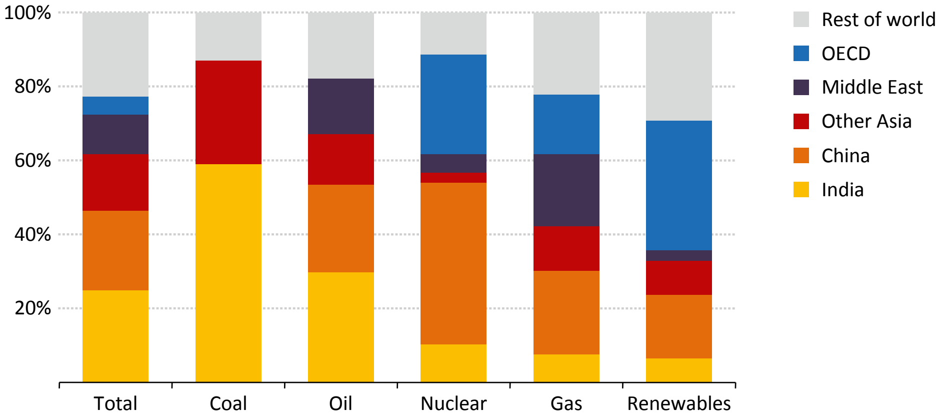
- India requires a cumulative $2.8 trillion in investment, an average of $110 billion per year, to meet the supply projections in the New Policies Scenario, 75% of which is in the power sector, and an additional $0.8 trillion to improve energy efficiency. Investment in energy supply is held at similar levels in the Indian Vision Case, largely because of an 80% increase in efficiency spending. Securing investment at these levels is a huge challenge, requiring an open and predictable regulatory framework and an expanded range of investors and sources of finance. Opening up new, long-term and low-cost financing options is critical to direct investment towards high efficiency and low-carbon technologies.

What route to centre stage?

Today's energy sector in India is already unrecognisable from the one that existed over two decades ago, prior to the start of widespread economic reforms in 1991. But the pace of change over the next twenty-five years promises to be even more dramatic, if energy is to be a spur and not a hindrance to India's development ambitions. The changes visible in this special focus on India are notable not just because of their sheer scale, but also because of the complexity and diversity of the energy system that emerges, both in operational terms and in terms of governance, with a greater range of players, fuels and technologies, and a requirement for sustained inflows of capital. This chapter draws out some of the wider implications of the prospective Indian energy transition, first on the basis of the projections of the New Policies Scenario and then, also, on the assumption that India goes yet further and faster - what we have dubbed the Indian Vision Case.

An unmistakable inference from our analysis is that India is heading for a central position in global energy affairs. Energy developments in India transform the international energy system, and India in turn will be increasingly exposed to changes in international markets. This is, in part, a function of the expanding size of the Indian energy sector and its share in the growth of consumption of key fuels: in the New Policies Scenario, India accounts for almost a quarter of the rise in global energy use to 2040, slightly more than China (Figure 4.1). But it is also related to the range and scale of connections that bind India's energy sector to the rest of the world: via trade in fossil fuels, transfers of technology, investment and also interactions in relation to emissions and environmental policies.

Figure 4.1 ▷ Share of India in world energy consumption growth by fuel in the New Policies Scenario, 2013-2040



Note: Shares are calculated only for those countries and regions where consumption is growing.

The New Policies Scenario anticipates the resolution of some major energy challenges facing India, including the long-standing objective of bringing access to electricity to all of the country's population. But reviewing the projected outcomes, as we do in the first part of this chapter, there is a sense not only of India's achievements but also of some continued, (even exacerbated) vulnerabilities, as well as of business that remains unfinished. The vulnerabilities span aspects of energy security – notably the extent of reliance on imports of crude oil – and a range of environmental issues including air quality, water stress and the implications of climate change.

The projections of the New Policies Scenario also fall short of India's policy and development objectives in a number of important areas, or see the achievement of these goals later than officially envisaged. This reflects the methodology of the New Policies Scenario – applied without discrimination to all countries and regions in our World Energy Model – which mandates a cautious assessment of the chances that policy intentions which are yet to be implemented will be fully and successfully realised. Inevitably, this approach provides a view that is not consistent with all aspects of India's own vision for its energy sector.

In an Indian Vision Case, we examine how India's energy system would evolve if key targets of that vision were met in full. At the heart of this analysis is the announced intention to put accelerated expansion of the manufacturing sector at the heart of India's growth model, together with rapid realisation of universal and round-the-clock power supply. Accomplishments in these areas is accompanied, in the Indian Vision Case, by even more rapid deployment of renewable energy, led by wind and solar power, reform in the coal sector that includes a faster transition to high efficiency in the coal-fired power fleet, a concerted push for greater efficiency across India's end-use sectors and a dedicated effort to tackle emissions of local pollutants and arrest the deterioration in India's air quality.

Realising India's energy objectives, whether at the pace anticipated in the New Policies Scenario or at the accelerated tempo of the Indian Vision Case, will require sustained investment, at levels that necessitate calling upon large-scale flows of private and foreign capital. This, in turn, will require thorough-going energy regulatory reform. In a concluding section of this chapter, we quantify these investment requirements, both for energy efficiency and for energy supply, and examine the measures that can help realise this investment and the risks that might lead it to fall short.

Implications of the New Policies Scenario

We consider, first, the broad implications of India following the path of the New Policies Scenario. Over the next two-and-a-half decades, energy is set to make a huge contribution to quality of life in India, powering the offices and factories in which people work, the cities in which an increasing number of them live, as well as the appliances and vehicles that rising incomes allow a bigger share of the population to buy. Even though average energy consumption per capita remains relatively low in India in the New Policies Scenario, at 60% of the global average even in 2040, the cumulative weight of rising individual energy needs in a rapidly expanding economy has a major impact on global trends.

Table 4.1 ▷ Breakdown of average household energy use in rural and urban areas in the New Policies Scenario

	Average ownership rate				Average household consumption*		Share in sector total consumption**	
	Rural		Urban					
	2013	2040	2013	2040	2013	2040	2013	2040
Cooling appliances	0.7	1.2	1.3	1.9	290	761	10%	27%
Refrigeration	0.1	0.5	0.5	1.0	361	405	4%	11%
Cleaning ***	0.0	0.1	0.2	0.6	171	193	1%	1%
Televisions and computers	0.6	1.6	1.0	2.1	102	112	4%	5%
Vehicles****	0.3	1.0	0.7	1.9	4.2	4.3	26%	36%
Number of households (million)	**175**	**208**	**90**	**190**				

* Average annual consumption of household appliances, in kilowatt-hours, for new appliances sold in India in 2013 and 2040; and fuel consumption in litres per 100 kilometres for new cars or motorbikes. ** The share in sector total consumption is the share of each category of appliances in the total consumption of the residential sector (excluding solid biomass) and the share of fuel consumption by cars and two- and three-wheelers in transport sector demand. *** Cleaning equipment refers to washing machines, dryers and dishwashers. **** Vehicles include both passenger cars and two- and three-wheelers.

Sources: Government of India, 2012; IEA analysis.

The projected energy consumption profile of an average Indian household in 2040 in the New Policies Scenario is very different from that of today, as the growth of middle-income households and urbanisation pushes up energy use. Middle-income groups[1] made up around 25% of total households in 2014, but this percentage rises to almost 80% by 2040. The average number of items of large energy-using equipment in each household increases and average electricity consumption stemming from such increased ownership is also expected to rise (Table 4.1).[2] We estimate that urban households in 2040 own, on average, one refrigerator or freezer by 2040, as well as two different cooling systems (fans, air conditioners or air coolers) and more than two electronic items (e.g. televisions and computers). Even though rural households do not reach the same levels of average ownership as their urban counterparts, their growth rate in average ownership levels is actually higher because they start in 2013 from a much lower base, due to low incomes and unreliable electricity supply. Similar trends are expected in personal mobility, accompanied also by a switch from two- and three-wheelers (which account for around 80% of the

1. Defined as households with an average income of household income INR 200 000-1 000 000 per year (approximately $13 000-65 000 per year in purchasing power parity terms or $4 000-20 000 per year in market exchange rate terms) (Beinhocker, 2007).

2. Although minimum energy performance standards for appliances are expected to lower the annual consumption of the most common appliances used by households in India, the size of new appliances added to the stock is expected to grow substantially, leading to a net increase in their average electricity consumption. The same logic is in play for vehicles, with the shift from two-and three-wheelers to cars offsetting improvements in fuel efficiency.

vehicles owned currently) to cars. The 320 million new cars projected to be sold in India from 2014 to 2040 boost energy consumption and absorb the equivalent of around 3% of India's cumulative production of steel.

India's urban population grows by some 315 million over our projection period and the statistics probably do not capture the full extent to which urban areas come to dominate economic life and energy consumption.[3] Even with the data that we use in the World Energy Model, urban areas account for three-quarters of the projected energy consumption growth in buildings (excluding solid biomass) and could also be expected to represent a large share of energy demand growth in transport. As underlined in Chapter 2, how urbanisation is planned and realised will have pivotal implications for India's energy prospects. For the moment, clay bricks constitute the main materials used for rural residential construction; the anticipated shift to steel and concrete-built urban houses and multi-story blocks, alongside a doubling in the average floor area per household, has striking implications for the production of a range of energy-intensive materials in India.

Well-managed urbanisation facilitates the provision of modern energy services. It is much easier to bring electricity and modern fuels, such as liquefied petroleum gas (LPG), to areas with higher population density, and access rates to electricity and clean cooking facilities in rural areas lag consistently behind those in towns and cities. Although universal rural electrification is ultimately achieved in the New Policies Scenario, the provision of clean cooking facilities to all is not, as LPG distribution networks are insufficiently developed and solid biomass remains readily available in most areas. Consumers across India become gradually more exposed to market prices for energy due to the removal of subsidies for the main fuels (transport fuels are already deregulated) and for electricity. Yet the implications for India's poverty reduction goals are mitigated by a strategic and prudent shift towards targeted protection for vulnerable consumers, increasingly through individual payments to bank accounts rather than interventions on end-user prices or tariffs.

In the case of electricity, the addition of more expensive sources to the power mix (notably wind and solar, but also more capital-intensive technologies for other fuels) increases the average capital cost of new power capacity. This increase is concentrated in the first half of our *Outlook,* after which declining capital costs for renewables flatten this trend. Given the social and political sensitivity of power tariffs to Indian consumers, this is a powerful reminder of the importance of cost-efficient policies in the power sector, including not just those relating to investment but also the procurement of fuels and renewable power and the reduction of transmission and distribution losses in the network. Governance of the power sector and the way that different plants are dispatched to balance the system becomes significantly more complex, not least because of the integration of variable renewable energy sources for power generation.

3. Densely populated but often partly informal settlements on the edge of major cities may not be included in the official classification of urban areas.

Affordable and reliable energy supply is essential for India's industrial performance. With its large infrastructure needs and growing urbanisation, India becomes a hub for energy-intensive production – cement, steel, glass, aluminium and other materials. As recognised in the "Make in India" campaign, a healthy manufacturing sector is an important way to provide employment opportunities for the one million that enter the job market each month as well as for those who shift from the agricultural sector (a theme developed in the Indian Vision Case later in this chapter). A well-functioning energy sector is a pillar of India's general strategy for job creation; the sector's own requirement for labour is also important in itself (Box 4.1).

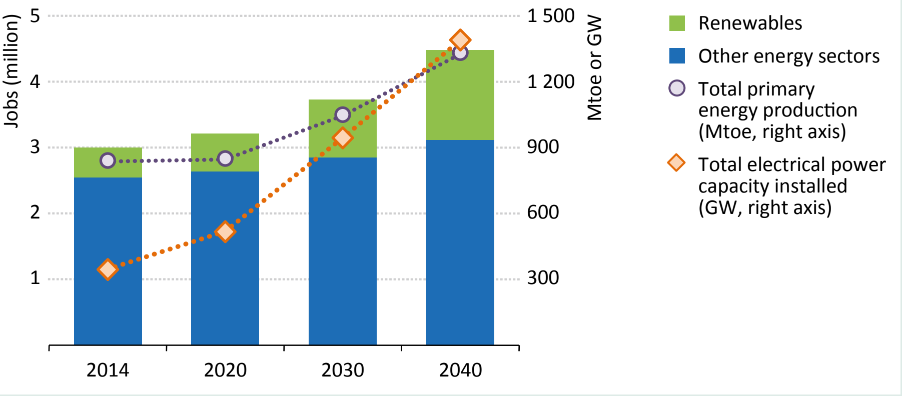
The outlook for the global coal industry in the New Policies Scenario is increasingly intertwined with energy choices made in India. Among those countries whose coal use grows, India represents around 60% of the growth in coal consumption worldwide (although total coal use is less than half of that in China in 2040). If all countries are taken into account, including those where coal consumption declines, the increase in India's coal demand is greater than the total net increase in global consumption. The growth in coal use is split between the power sector and industry, the share of the latter underlining the challenge that India faces in curbing carbon-dioxide (CO_2) emissions. While low-carbon alternatives to coal are available in the power sector and policy in India is actively seeking to increase their deployment, finding substitutes for coal for process heat and steam in industry is a much more difficult task (and using carbon capture and storage [CCS] to turn coal-based processes into low-carbon production routes in India remains reliant on increased global support for CCS technology).

Box 4.1 ▷ Employment gradually turning green in India's energy sector

Data on the total number of jobs in India's energy sector are sparse, but we estimate that there are approximately three million people currently employed; extracting energy, transporting it, manufacturing energy-supply equipment and building and maintaining energy-supply infrastructure, including power plants, transmission lines, refineries and liquefied natural gas (LNG) terminals. The total could almost double if those whose employment depends indirectly on the energy sector are included, such as providers of intermediate components or equipment or those providing services, such as accounting, legal or finance.

The majority of India's energy jobs today are in the coal sector, including just under half a million in coal extraction and transportation and more than one million in different aspects of the construction and operation of coal-fired power plants. Our estimate for employment in renewable energy (excluding commercial marketing of solid biomass, but including large hydropower) is also just shy of 500 000. In the New Policies Scenario, energy sector employment rises, not least because a greater share of the necessary equipment is assumed to be manufactured in India; but growth in employment is less rapid than the increase in energy use as a whole, reflecting the rise in energy imports and a projected increase in labour and technological productivity (Figure 4.2). There is a marked shift towards jobs in renewable energy, which account for more than 30% of total energy supply jobs in 2040, up from 15% in 2014.

Figure 4.2 ▷ Estimated number of direct jobs in India's energy supply sector in the New Policies Scenario



Note: Mtoe = million tonnes of oil equivalent; GW = gigawatts.

Sources: Ministry of Labour (2013); REN21 (2015); Council on Energy, Environment and Water and Natural Resources Defense Council (2014); Rutovitz (2012).

The skills required to run the Indian energy sector change over the coming decades, requiring an intensified effort with training and vocational education. There is less emphasis in the future on unskilled labour (as, for example, in coal extraction) and a rise (from 25% to 35%) in the estimated requirement for semi-skilled and skilled workers, such as engineers, project managers, technical staff, equipment operators and installation and maintenance teams for solar panels and other renewable energy technologies.

Despite the continued predominance of coal, there is a clear trend towards greater diversity in the power mix, due to the rise of renewables (low-carbon sources account for more than 50% of the new power generation capacity added to 2040) (Table 4.2). However, the analysis also points to one area of potential vulnerability: the rise in India's requirement for imported oil. Dependence on oil imports rises to over 90% by 2040, from around three-quarters today, with very strong reliance on the Middle East. Though international trade in oil can consolidate international relationships, experience over the last half-century highlights the need to make prudent provision against unexpected supply interruptions, through measures to ensure emergency preparedness and co-operation with other oil stockholding countries.

Table 4.2 ▷ Selected energy indicators for India in the New Policies Scenario

	2013	2025	2040
Energy mix			
Energy use per capita relative to global average	33%	44%	60%
Diversity of the primary energy mix*	0.14	0.14	0.15
Share of India in global fossil-fuel consumption	5%	8%	12%
Power sector			
Power generation capacity (2013=100)	100	222	409
Diversity of the generation mix*	0.49	0.35	0.27
Share of non-hydro renewables in generation	5%	13%	17%
Access to energy			
Access to electricity (%)	81%	92%	100%
Access to clean cooking (%)	33%	45%	70%
Investment and expenditure			
Total investment in energy supply (2013=100)	100	148	209
Average cost of power capacity (2013=100)	100	159	158
Net fossil-fuel import bill as share of GDP (MER)	7%	6%	5%
Household energy spending as share of income	2%	3%	4%
Imports			
Coal import dependence (%)	29%	37%	31%
Net oil import dependence (%)	74%	83%	91%
Total crude imports as a share of global trade	10%	12%	16%
Crude oil import diversity*	0.29	0.31	0.33
Natural gas import dependence (%)	34%	53%	49%
Import diversity*	0.76	0.35	0.05
Sustainability			
Energy intensity of GDP (2013=100)**	100	66	45
Carbon intensity of power (2013=100)**	100	81	71
Emissions of NO_x, SO_x and $PM_{2.5}$ (2010=100)***	100	155	227
CO_2 emissions as a share of global emissions	6%	9%	14%
CO_2 emissions per capita relative to global average	30%	58%	79%

* Indicators for diversity are calculated as a Herfindahl–Hirschman Index and normalised for values between 0 and 1, where 0 = complete diversity (i.e. each element having an equal share) and 1 = complete concentration (i.e. one element having a 100% share). High values or values that increase over time indicate high or growing dependence on a single element of the calculation. The categories in the energy mix are: coal, oil, gas, traditional use of biomass, low-carbon energy (nuclear and renewables). The variables for the power mix are: coal, oil, gas, nuclear, hydropower, bioenergy, wind, solar, other renewables. The sources of oil and gas imports are divided between: North America, South America, Middle East, Russia, Caspian, Africa, Southeast Asia and Australasia.

** Energy intensity is measured as tonnes of oil equivalent per $1 000 of GDP ($2014). Carbon intensity of power generation is measured as grammes of CO_2 per kWh. Both are normalised to a value of 100 for the base year of 2013.

*** Total pollutant emissions of sulphur and nitrogen oxides and particulate matter are calculated in tonnes per year, based on emission limit values and fuel quality standards as adopted by mid-2015, normalised to a value of 100 for the base year of 2010.

Last but far from least, there is the question of environmental impacts. India has been explicit in setting a target of faster, sustainable and more inclusive economic growth as the cornerstone of its approach to development. The energy sector is central to the issue of sustainability because of its role as the primary source of local air pollutants and greenhouse-gas emissions (GHG), as well as its need for water. The potential implications of the New Policies Scenario for India's air quality, described in Chapter 2, already indicate the negative spillovers from energy production and use on the scale envisaged. Stresses are also visible in relation to other natural resources, including water and land, where the needs of the energy sector are not trivial. Under-playing or under-pricing environmental risks cannot be the basis for sustainable growth in India's energy sector or its economy as a whole.

Energy-related CO_2 emissions and climate change

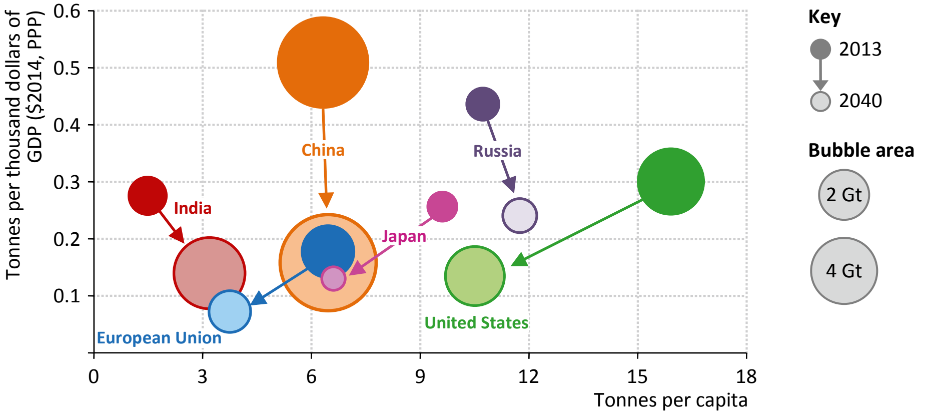
India is among the most vulnerable countries when it comes to the impacts of a changing climate (we highlight below just one aspect of this, the potential effects of water scarcity – which could be exacerbated by climate change – on the operation of India's coal-fired power fleet). India therefore has a strong interest in concerted and effective global action on GHG emissions, even though, despite its population and size, India has accounted for a small share of the cumulative GHG emissions released into the atmosphere thus far: only 3% of historical energy-related CO_2 emissions since 1890. Per-capita emissions, at 1.5 tonnes of CO_2 in 2013, are around one-third of the global average. The domestic and international challenge for India is to demonstrate serious intent to limit emissions, reducing the rate at which emissions grow in the future, while still preserving sufficient headroom to allow for growth in the economy. The government has committed to keep its per-capita emissions below the level of those of industrialised countries in the future and, as part of its Intended Nationally Determined Contribution (INDC) submitted in October 2015, it has also pledged to reduce the emissions intensity of the economy by 33-35% by 2030, measured against the level in 2005.

Whatever the scenario, India will need increasing volumes of energy to achieve its development goals. In the New Policies Scenario – and in every other scenario prepared by the *World Energy Outlook* (WEO) including the 450 Scenario (that is consistent with limiting the long-term global average temperature increase to 2 degrees Celsius) – India's energy-related CO_2 emissions are higher in 2040 than in 2013. There is, though, a huge variation in the projected level of these future emissions trajectories, depending both on the level of energy use and also on the extent to which India locks into a high-carbon development path.[4] In the New Policies Scenario, the carbon intensity of India's economy improves substantially, but India's emissions rise from 1.9 gigatonnes (Gt) in 2013 to 3.7 Gt in 2030 and around 5 Gt in 2040, meaning that emissions per capita converge towards the global average (3.2 tonnes of CO_2 per capita in India in 2040, versus a global average that

4. A wide range of future demand and emissions trajectories emerge from different national scenario-based modelling efforts (Dubash et al., 2015).

edges downwards to 4.1 tonnes of CO_2 per capita) (Figure 4.3). This increase in emissions means that India is the largest single contributor to the rise in global emissions over the projection period. Although it includes steps towards a more sustainable pathway for India, the New Policies Scenario falls well short of exhausting the scope for further action.

Figure 4.3 ▷ Energy-related CO_2 emissions by selected country and region in the New Policies Scenario



Notes: PPP = purchasing power parity. Bubble area represents total energy-related CO_2 emissions.

Focus: water and climate change

A significant share of India's large population lives in areas already vulnerable to floods, cyclones and drought, with rising sea levels also threatening displacement along the country's densely populated coastlines. Similarly, a large share of the population is dependent on climate-sensitive sectors like agriculture, fisheries and forestry for its livelihood. A precise assessment of the nature and timing of climate impacts is inherently difficult, but climate change is expected to make India's monsoons more unpredictable, with a likelihood of higher seasonal mean rainfall, accompanied by an increased possibility of both prolonged periods of heavy precipitation and dry weather. The high dependency of Indian agriculture on monsoons means that changes in their pattern can have strong repercussions on the yields of food crops and bioenergy, as well as affecting hydropower and water security. Heat waves, like the extreme temperatures experienced in India in May 2015, are expected to become more frequent, increasing both the risks to the population and the demand for cooling appliances (Hijoka et al., 2014).

The impact of climate change on water balances (both spatially and temporally) is an increasing concern for energy supply and power generation around the world. Although agriculture is by far the largest water-using sector in India, irrigation and livestock accounting for more than 90% of total water withdrawals, energy policy decisions could have a significant impact on future water security, via policy on electricity tariffs and metering in the agricultural sector (as discussed in Chapter 2). Water availability, under the impact of climate change, could also become an increasing constraint on India's energy sector, not only for hydropower and bioenergy, but also for many other areas, such as thermal power plants. India's coal-fired power sector has already faced constrained water availability – water shortages have caused shutdowns of coal-fired power stations, including the Chandrapur and the Parli plants in recent years. How these water-energy links might evolve is taken up in more detail below.

Thermal power plants (including fossil-fired and nuclear) require some form of cooling and, within the power sector in India, coal-fired power plants are responsible for around 95% of total water withdrawals, the rest being split between gas-fired and nuclear power stations. The cooling technology used – together with the overall efficiency of the power plants – determines the amount of fresh water that is withdrawn from local sources (water withdrawals) and the amount that is withdrawn but not returned to the local water basin (water consumption) (IEA, 2012). The options are:

- Once-through (or open-loop) cooling: water is withdrawn from surface sources and returned to the source at a higher temperature, after it has passed through the condenser. Once-through systems typically withdraw up to 60 times more water than wet-tower systems, but the level of water consumption is much lower.
- Wet-tower (or closed-loop) cooling: withdrawn water is managed in an internal re-use cycle, with water passing through the condenser being pumped to the top of a cooling tower and then collected at the bottom of the tower. Some water is lost through evaporation. The capital cost is typically higher than once-through systems.
- Dry-cooling: large volumes of air are passed over a heat exchanger and limited amounts of water are withdrawn and consumed. Dry-cooling systems use substantial amounts of electricity, effectively lowering the power output of the plant. Dry-cooling systems usually require higher capital investment than other cooling systems.

Constraints on water availability influence the location of power plants, as well as the choice of cooling technologies for new plants and for retrofitting existing plants. In 1999, India's Ministry of Environment and Forests banned the construction of thermal power plants that use once-through cooling systems and introduced a zero discharge policy that requires operators to re-use water.[5] Older plants, built prior to this decision still run on open-loop systems, as it is not cost-effective to retrofit them (WWAP, 2014). As of 2014, most Indian plants use wet-tower cooling (Figure 4.4).

The use of dry-cooling technology plays only a minor role in the Indian electricity system today. However, the results of a detailed spatial modelling exercise, based on the projections in the New Policies Scenario, show that water stress is likely to have an increasingly material impact on the choice and deployment of cooling technologies (and the related costs) in India. A significant increase is projected in the use of dry-cooling in arid areas in northern India, including Uttar Pradesh and Rajasthan, and in the south in Karnataka. In total, 31 gigawatts (GW) of installed coal-fired capacity is projected to be equipped with dry-cooling systems by 2040.

5. An exception was made for power plants located in coastal areas, which can use seawater as a coolant.

Figure 4.4 ▷ Installed coal-fired power generation capacity in India by cooling technology in the New Policies Scenario

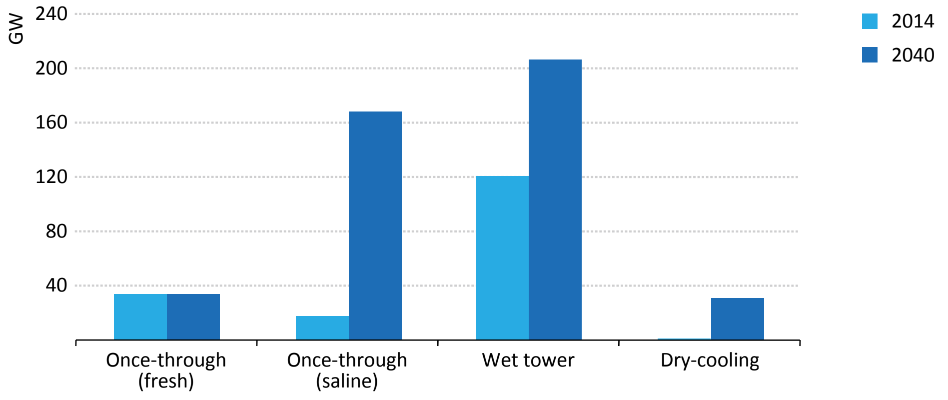
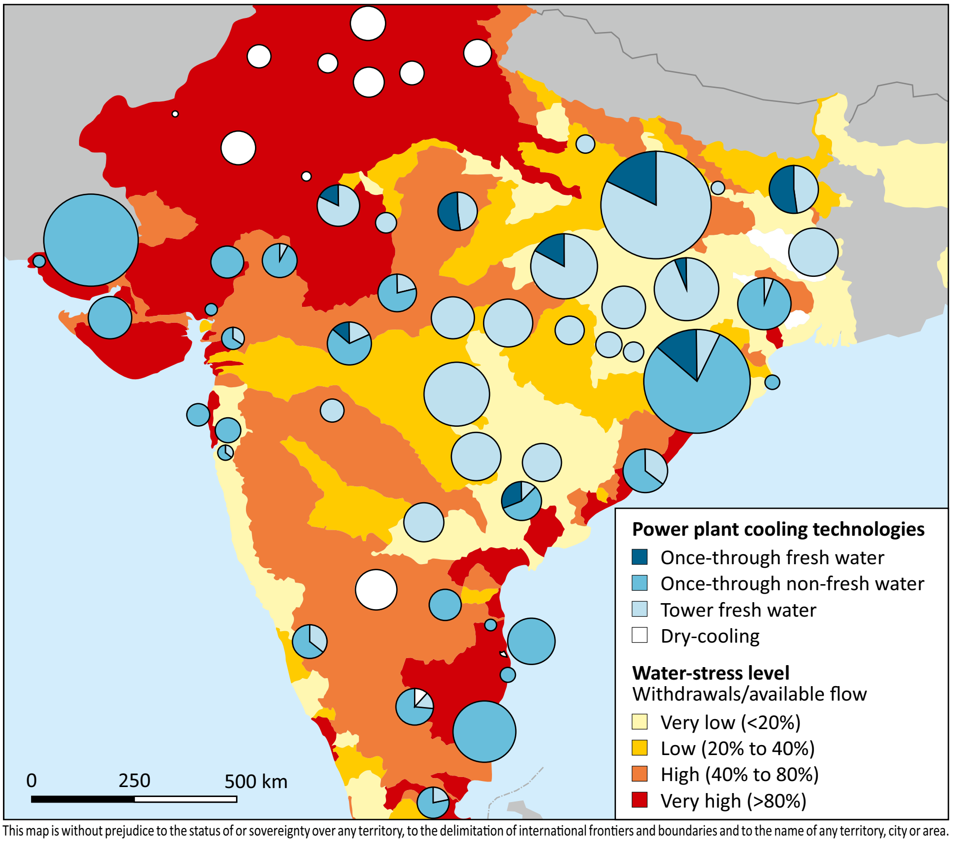


Figure 4.5 ▷ Installed coal-fired generation capacity by cooling technology and sub-catchment area in selected regions of India, 2040



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: The size of the pie charts corresponds to the cooling technology of the capacity installed. The smallest pie charts represent 200 MW and the largest 46 GW.

Coal mines in India are located mainly in the east (in the states of Odisha, Chhattisgarh and Jharkhand), which does not experience water stress today nor is it expected to do so in 2040 (Figure 4.5). In order to reduce coal transportation costs, and where demand centres are not too distant, significant amounts of coal-fired power generation capacity are projected to be built in relative proximity to the coal mines, in which case they predominantly use a wet-tower cooling system. Along the coast, new coal-fired power plants primarily rely on imported coal and use seawater as a cooling medium, giving them a cost-advantage for transport and limiting their exposure to water stress. This is one of the reasons why coal-fired capacity with saline once-through cooling systems increases from less than 20 GW today to more than 165 GW in 2040 in the New Policies Scenario.

The additional investment for cooling systems over the projection period, compared with a system that faces no water stress, is around $30 billion. That this sum is not larger is ultimately due to the fact that coal mines are, typically, not located in water-stressed areas and so the need for dry-cooling for power plants is limited. In total, water-related factors lead to a 6% increase in the share of generation costs related to fuel transport, cooling systems and network expansion.

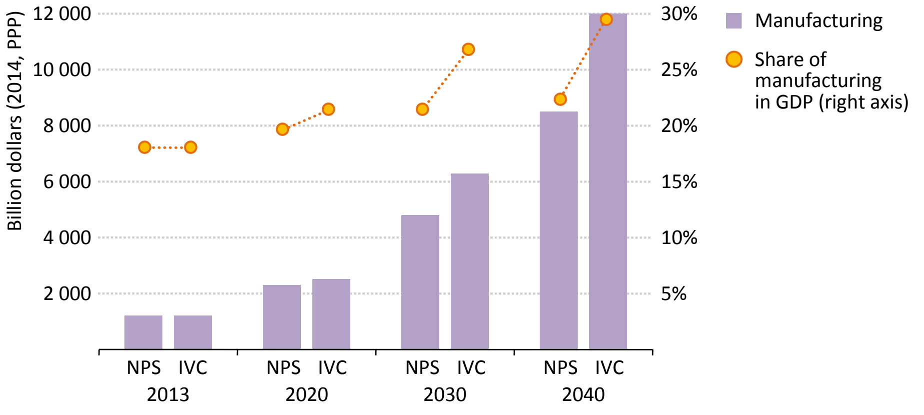
An Indian Vision Case

The vision India has defined for its development – two pillars of which are universal round-the-clock electricity supply and an expanded share of manufacturing in gross domestic product (GDP) under the "Make in India" campaign – would have profound implications for its energy system. We explore these implications, through an additional detailed modelling effort, in an Indian Vision Case in which India attains these key objectives in full and according to an accelerated timetable, thus putting itself on a different path of economic growth. The essential points that differentiate the Indian Vision Case from the New Policies Scenario are:

- The share of manufacturing in India's GDP rises to 25% by the mid-2020s and to 30% by 2040 in the Indian Vision Case, compared with a more modest rise in the New Policies Scenario (Figure 4.6). GDP rises to an annual average of 6.8% per year, versus 6.5% in the New Policies Scenario.[6]
- Investment in the power sector accelerates more quickly than in the New Policies Scenario, so as to ensure a faster improvement in the reliability of power supply and achievement of full universal access to electricity within ten years.

6. The GDP assumption in the Indian Vision Case includes the same expansion of the services sector as in the New Policies Scenario, leading to a higher rate of overall GDP growth. The implications for agriculture are discussed later in this section.

Figure 4.6 ▷ Value added in manufacturing in the Indian Vision Case compared with the New Policies Scenario



Note: NPS=New Policies Scenario; IVC=Indian Vision Case; PPP = purchasing power parity.

These achievements are complemented by more rapid movement in four additional areas:

- A strong push to promote energy efficiency in all of India's end-use sectors: buildings, transport, industry and agriculture.
- A more thorough modernisation of India's coal sector, including a faster transition to more efficient coal-fired technologies in the power sector.
- Accelerated deployment of renewable energy, based on the goal to see total renewable capacity in the power sector (excluding large hydropower) reach 175 GW by 2022, with further expansion after this date.
- A suite of measures to control the emissions of sulphur, nitrogen oxides and particulate matter that cause the low air quality in India's major cities.

Making the manufacturing sector the engine of India's growth, rather than the services sector (which has been the prime driver of GDP growth in recent years) means a significant acceleration in the amount of energy required to fuel India's development. Over the *Outlook* period, generating $1 of value added through expansion of industry requires at least ten-times more energy than $1 of value added from the less energy-intensive services sector. An emphasis on manufacturing also implies some far-reaching changes across Indian society: increasing employment opportunities in urban and peri-urban areas; triggering additional migration from rural to urban areas and increasing average wages. Increasing urbanisation and higher incomes push residential energy demand higher, as – to a lesser extent – does the more rapid achievement of universal access to electricity (Spotlight).

S P O T L I G H T

What mix of technologies can achieve universal electricity access in India?

In the Indian Vision Case, all households in both urban and rural areas gain access to electricity within ten years, earlier than projected in the New Policies Scenario. This involves not only a swift pace of electrification in and around India's urban centres, but also brings electricity to the entirety of the rural population, with the help of a range of different generation technologies. Taking additional account of population growth, around 390 million people become new consumers of electricity over the period to 2025 in the Indian Vision Case, either via a grid connection or decentralised systems.[7]

In urban areas, the most economic option is always on-grid electrification; but in rural areas the final technology choice depends on a variety of factors: population density is one of the main variables, but others include the technology costs for mini- and off-grid systems, the cost of diesel and the comparison between grid-electricity tariffs and mini- and off-grid tariffs. A further dynamic consideration relates to rising household incomes: these have a strong impact on per-capita electricity demand and mean that the capacity of electricity systems needs to be scaled up over time. Off-grid systems can provide vital initial access for remote communities, but are less able to accommodate rising energy needs as households buy new appliances.

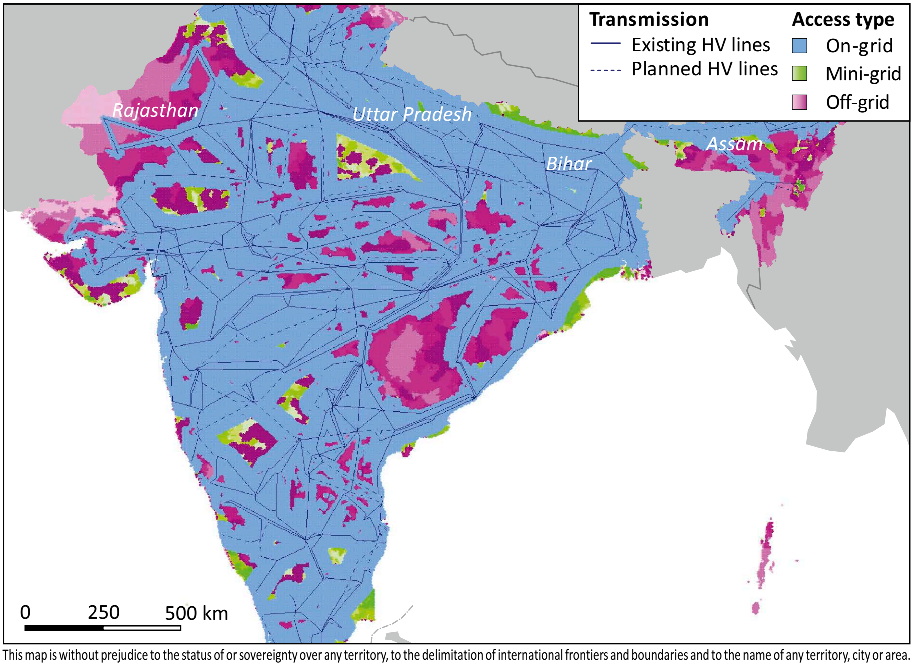
Based on the anticipated expansion of the main transmission lines in India over the next ten years, a detailed spatial analysis has been undertaken to illustrate the optimal technology split to achieve universal access (Figure 4.7).[8] For the 240 million people without access today, around 25% gain access via the grid, 35% via mini-grid systems and 40% via off-grid systems. Although mini- and off-grid solutions play an important role in bringing power to the rural population of India, on-grid connections remain the dominant overall type of electricity connection in 2025.

As can be seen from the map, decentralised systems are most cost-effective in regions with low population density, such as the state of Assam in the north-eastern part of the country or west Rajasthan. In the states of Bihar and Uttar Pradesh, accounting collectively for one-third of the total rural population and 60% of the population without access today, a higher share gain access via the grid: population density is higher in these two states and additional transmission lines are already planned or under construction.

7. Note that a decentralised grid and a low-carbon electricity system are not synonymous: wind power is low carbon but not decentralised, as wind farms rely on a centralised grid to deliver electricity to consumers. India also has a large fleet of diesel generators, which are decentralised but not low-carbon. Solar PV is theoretically more suitable for low-carbon and decentralised electrification, but so far the majority of solar deployment in India has been large-scale ground-mounted projects that, from a system perspective, are power plants feeding the centralised grid.

8. The geographic analysis was developed in collaboration with the KTH Royal Institute of Technology (Sweden), division of Energy Systems Analysis (KTH dESA).

Figure 4.7 ▷ Optimal split by grid type to achieve universal access in selected regions in the Indian Vision Case by 2025



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

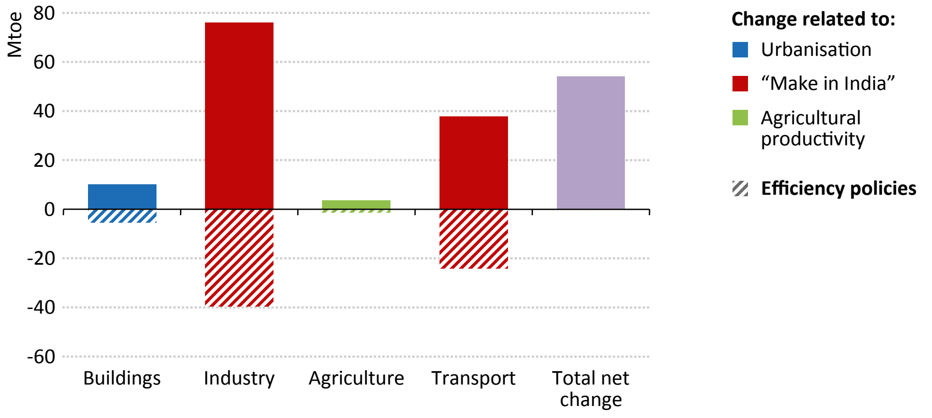
Note: The analysis incorporated the planned expansion of the main transmission lines. The density of the colour is linked to population density: the darker the colour, the higher the population density. The regions selected are those with the highest deficit in terms of population without access.

Within the mini- and off-grid systems, diesel generators provide the largest share of generation, followed by solar photovoltaic (PV) systems. The cost of solar PV falls over time and the technology is anticipated to become more and more competitive, compared with diesel generators (with which they may, in practice, be used in tandem to improve reliability). Small hydropower and wind power also contribute to the mini- and off-grid mixes, but their deployment depends on the existence of suitable local conditions, and this limits their share in generation. The investment associated with this drive for universal access is around $60 billion in total. Three-quarters of this sum goes to new mini- and off-grid power generation capacity, followed by investments in on-grid capacity and extension of transmission and distribution lines.

The net result of just these two changes (the increased share of manufacturing and the faster attainment of universal and reliable electricity supply) would be to push total final energy consumption in 2040 up by 15% (or 170 million tonnes of oil equivalent [Mtoe]) above the levels seen in the New Policies Scenario. Such an outcome would exacerbate all the strains described earlier in relation to the New Policies Scenario, increasing energy import needs, putting additional pressure on water resources and the required pace of infrastructure development, higher CO_2 emissions and a further deterioration in air quality.

That is why the other components of the Indian Vision Case assume even more importance than in the New Policies Scenario, to keep the adverse energy and environmental implications in check. Strong enforcement of energy efficiency policies, across all sectors will be essential – a drive consistent with the underlying vision of the "Make in India" campaign, which aims to safeguard the environment while generating industrial growth. Pushing in the same direction, rapid deployment of renewables reduces the carbon intensity of growth while also lessening the call on imported energy.

Figure 4.8 ▷ Change in fossil-fuel demand in the end-use sectors in the Indian Vision Case compared with the New Policies Scenario, 2040



Our analysis shows that increasing value added to the industrial sector by one-quarter by 2040 (compared with the New Policies Scenario) can be achieved while adding "only" 7% (or 48 Mtoe) to industrial energy demand, 35 Mtoe of which comes from fossil fuels (Figure 4.8). However, this requires a heavy commitment to energy efficiency across the industrial sector. This encompasses not only energy-intensive sectors (where efficient use and re-use of materials can play a vital role, Box 4.2) but also the less energy-intensive industries that are targeted by the "Make in India" campaign (such as textiles, food processing, machinery and industrial equipment), which have significant energy savings potential. For the energy-intensive sectors, the coverage of the "Perform, Achieve and Trade" scheme is extended, as already envisaged in the second-cycle for the period from 2016, and the requirements tightened significantly to bring efficiency standards in these industries close to global best practice levels by 2040. Particular attention needs to be paid to the Indian steel industry, which is projected to account for almost 20% of industrial energy demand by 2040, but in which current average efficiency levels are relatively low by global standards.

The need to focus on energy efficiency does not stop with the industrial sector. The increase in manufacturing output in the Indian Vision Case also implies a 30% rise in freight activity – and a potentially significant upward jolt to oil demand for transportation. Introducing efficiency standards for heavy and medium trucks and light commercial vehicles becomes a pressing need in order to constrain oil imports and to limit the air pollution from exhaust gases. These measures, which improve the efficiency of new heavy trucks from 33 litres per 100 km today to 21 litres per 100 km in 2040 (in line with best practice in other developing Asian countries) can contain growth in transport energy demand to 4% (or 12 Mtoe) in 2040 above the level in the New Policies Scenario, with the difference explained mostly by higher consumption of diesel for trucks.

Box 4.2 ▷ Material efficiency in energy-intensive industries in India

Energy-intensive industries, including steel, cement, plastics, aluminium and paper, are a pillar of India's industrialisation. In the Indian Vision Case, these five energy-intensive industries still account for more than 40% of total industrial energy consumption and almost a quarter of total final energy consumption in 2040. While a large share of the economically viable energy efficiency potential is exploited in the Indian Vision Case, most of the energy savings potential lies outside the energy-intensive sectors. Material efficiency – delivering the same material service with less overall material input – can complement energy efficiency in reducing energy demand, increasing energy security, enhancing economic competitiveness and reducing greenhouse-gas emissions. Material efficiency includes a set of diverse measures, such as increasing recycling, reducing the weight of consumer products, increasing fabrication yields and using energy-intensive materials more intensely. The government's Zero Effect, Zero Defect concept, launched in 2015, is an important step in the direction of encouraging companies to focus on product quality while reducing waste of natural resources.

Implementing material efficiency strategies, in addition to energy efficiency, in the Indian Vision Case can save almost 65 Mtoe (or 20% of energy demand from energy-intensive industries), which is significantly more than efficiency-related savings in these industries. Coal demand would be reduced by almost 50 Mtoe, demand for electricity and for oil by 7-8 Mtoe each. Three-quarters of total savings would arise from the steel sector, which is also by far the most important energy-consuming industry. The demand for steel can be reduced by using steel components for longer, light-weighting steel products, particularly in buildings and by reducing losses during the manufacturing process. Additionally, modernising India's recycling industry, which is currently highly fragmented in the absence of a legal framework, would help to increase recycling rates, which are currently one of the world's lowest, and thus replace energy-intensive primary steel with less energy-intensive secondary steel.

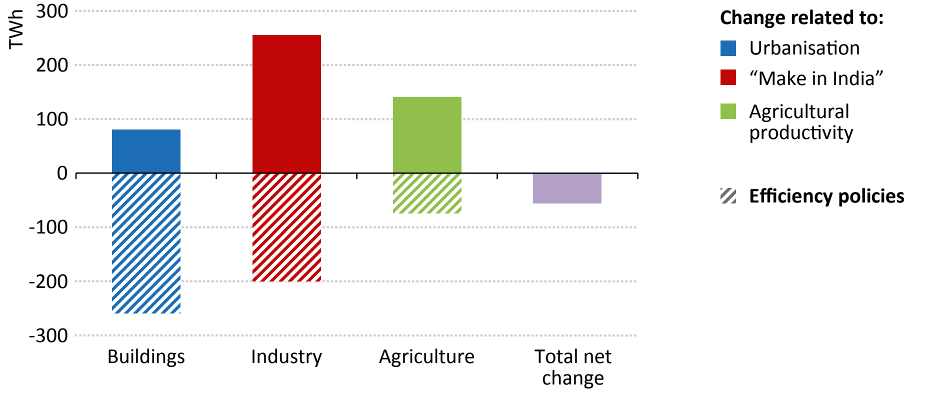
The expansion of the manufacturing sector requires labour: the Indian government is aiming to create 100 million additional manufacturing jobs by the early 2020s, bringing new employment to people who would otherwise mostly be employed in the agricultural sector. This implies additional growth in agricultural productivity to compensate for the loss of labour while still delivering the food that India requires. The two main contributions to this increase in agricultural productivity in the Indian Vision Case are a partial consolidation of the fragmented landholdings in many parts of India and growing mechanisation. The latter, in combination with a slight rise in the demand for irrigation, pushes up energy demand in agriculture in the Indian Vision Case by around 16%, or 8 Mtoe, in 2040, compared with the New Policies Scenario.

There are also strong implications for the residential and services sectors. Achieving the "Make in India" target would increase the number of job opportunities in and around India's towns and cities, accelerating the pace of urbanisation. Urban households consume, on average, about twice the amount of electricity of rural households that have electricity; urbanisation also facilitates access to alternative cooking fuels such as LPG, leading to extra consumption of oil and, to a lesser degree, also of gas. We estimate that the number of urban households would rise to 145 million by 2025 and 221 million by 2040 (see Table 4.1 for a comparison with the New Policies Scenario). The earlier achievement of universal access to electricity increases residential electricity demand in total by an extra 14 TWh in 2025. However, by 2040, this increase in electricity use is completely offset by the effect of efficiency policies. As standards become more stringent for household appliances and buildings, so household electricity consumption is lowered in the Indian Vision Case below the levels of the New Policies Scenario.

Improving efficiency across a range of residential appliances is vital to counteract the upward pressure on demand in the buildings sector. As of today, only one kind of refrigerator and one type of air conditioner are subject to mandatory standards, the other major appliances are still under a voluntary scheme. By gradually phasing out the least-efficient two categories of refrigerators and washing machines, and the least-efficient categories of televisions and computers, and by allowing only the sale of compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps for buildings and public lighting, electricity demand for lighting and appliances (even though the total number of appliances is higher) is around 80 terawatt-hours (TWh) lower in the Indian Vision Case compared with the New Policies Scenario. In order to offset further the effects on electricity consumption in buildings (not just from appliances) arising from urbanisation and universal access, the extension of the Energy Conservation Building Code to larger residential buildings brings down energy needs for cooling and saving by almost 90 TWh.

Despite the higher economic growth in the Indian Vision Case, efficiency measures taken on the demand side mean that electricity demand is lower in 2040 than in the New Policies Scenario (Figure 4.9), and the environmental footprint of the power sector is further reduced by changes in the way that this power is produced. The share of coal in power generation drops towards half in 2040, from around three-quarters today and the average efficiency of coal-fired generation improves more quickly, to reach 39% in 2040. The share of non-fossil fuel capacity in power generation – mostly non-hydro renewables – increases to almost 50% in 2040. Alongside the measures to improve the functioning of the power sector as a whole, discussed in Chapter 2, this would require the creation of a business and investment framework capable of attracting the necessary investment, as well as a step up in the amount of capital that flows to renewables. The latter, in particular, would need readily available and low-cost capital secured either through explicit guarantees or as a result of the reduced risk that comes with a predictable business framework.

Figure 4.9 ▷ Change in electricity demand in the end-use sectors in the Indian Vision Case compared with the New Policies Scenario, 2040



Note: The increase of electricity demand due to earlier achievement of universal electricity access is offset in 2040 by efficiency savings.

The Indian Vision Case takes important additional steps in the direction of a low-carbon development strategy for India, compared with the New Policies Scenario, even though the eventual outcomes, in terms of energy demand and emissions, are similar. Some of the key policy elements in this case – the strong accent on end-use energy efficiency, no further construction of the least-efficient coal-fired power plants, and increased investment in renewable energy technologies – coincide with the pillars of a scenario, called the Bridge Scenario, presented in the *Energy and Climate Change: World Energy Outlook Special Report* (IEA, 2015) that is designed to deliver a peak in global energy-related emissions by 2020.[9] The Indian Vision Case does not illustrate, by any means, the full potential for India to deliver a low-carbon model of growth, but India's readiness and ability to push far beyond the efficiency measures and renewables deployment in the Indian Vision Case depends on external leadership, too, for example in developing and proving technologies like CCS as well as mechanisms to channel low-cost financing for efficiency improvements and low-carbon investment.

9. India's energy-related CO_2 emissions in the Bridge Scenario are considerably lower than in the Indian Vision Case because the policy measures are stronger and assumed GDP growth is lower.

Box 4.3 ▷ Five steps to improve India's air quality

Proven emissions control technologies are available to maintain acceptable levels of air quality in India, even with the pressures arising from a growing economy and increasing combustion of fossil fuels for power generation and in the end-use sectors.[10] In parallel with efforts to improve the efficiency of power generation, the package of advanced control measures in the Indian Vision Case involves:

- Tighter controls on emissions from large combustion plants. These would be more stringent for new plants but also require the retrofit of existing plants with appropriate equipment like flue gas desulphurisation, NO_x controls or high efficiency de-dusters. Measures would also include a requirement to use best available technologies for certain industrial processes, including energy-intensive industries such as iron and steel, cement, chemicals and others.
- The introduction of maximum sulphur content requirements for liquids fuels, at the level of 1% for heavy fuel oil, 0.1% for light fuel oil and sulphur-free fuels (a maximum of 10 parts per million) for transport.
- Higher standards for exhaust emissions from road vehicles, up to the equivalent of Euro 6 for light-duty cars and trucks, Euro 6 for heavy-duty trucks and Euro 3 for motorcycles and mopeds, along with measures for non-road vehicles (tractors and other agricultural/construction vehicles, trains, ships etc.).[11]
- Low-cost measures to control emissions of volatile organic compounds from liquid fuels production, storage and distribution, such as leak detection and more efficient covers and seals.
- Accelerated roll-out of improved efficiency biomass cookstoves, accompanied by continued efforts to encourage switching from solid biomass to LPG and electricity.

Another element of the Indian Vision Case reinforces the importance of the environmental dimension to India's growth model – the need for measures to reduce emissions of local pollutants, so as to improve air quality and reduce the adverse effects of these emissions on human health. We estimate that enforcement of a suite of best practice measures, phased in over ten years to 2025, would allow for an 80% reduction in sulphur-dioxide (SO_2) levels in 2040, compared with the baseline of no additional action, mainly due to tight SO_2 emission limits in the power generation sector and in industry (Box 4.3). Emissions of nitrogen oxides (NO_x) would also fall by around 65% over the same period, with the largest reduction in the road transport sector. Emissions of particulate matter ($PM_{2.5}$) would decline because of tighter controls over industrial emissions as well as a decrease in household use of traditional biomass cookstoves. Some of these measures are already under discussion in

10. The emission standards and measures included are based on legislation in force in the European Union.

11. Standards that are currently in force in India for road sources are Euro 3/III for light-duty/heavy-duty vehicles India-wide and Euro 4/IV in selected cities.

the Indian government; others would go beyond anything currently under consideration.[12] These measures come at a significant financial cost, almost $90 billion per year on average to 2040 – more than double the amount that would be required under current legislation. But the benefits include a reduction in crop losses caused by ground level ozone, as well as a significant reduction, by more than one million per year, in premature deaths associated with local pollution.

Investing in India's energy future

Over the long term, safeguarding Indian energy security – in all its multiple dimensions – comes back to issues of investment.[13] The levels of investment required in the New Policies Scenario – even more so in the Indian Vision Case – are a large step above anything achieved by India so far, particularly in the power sector. Ensuring that this investment comes in a timely way depends not only on providing appropriate conditions within the energy sector itself but also a host of more general issues related to the overall complexity of the Indian business climate, which are very much the focus of the current government. Financing too is potentially a major obstacle, given that traditional resources of capital to expand the Indian energy sector (including public funds) may not be sufficient to meet its needs. This section describes the overall investment needs of the New Policies Scenario and the Indian Vision Case, both for energy supply and for energy efficiency, policy actions that can enable these to be met – as well as some risks and implications for India if investment falls short.

Investment in energy efficiency

Energy efficiency policies in India are growing in scope and importance, contributing to the mitigation of the prospects of energy consumption growth. In industry, the Perform, Achieve and Trade (PAT) scheme covers large industrial energy consumers, while the Indian government has put in place a suite of measures to raise awareness and provide financial support to improve energy efficiency in small and medium enterprises (SMEs). In transport, India introduced its first fuel-economy standard in 2014 (for passenger light-duty vehicles) and standards for heavy-duty vehicles are expected to be introduced in 2016. In buildings, India has introduced a voluntary energy code for commercial buildings (that has been made mandatory in several states), while more and more minimum energy performance

12. The emission limits from combustion in large boilers in the Indian Vision Case are similar to the values in a proposal made in 2015 by the Indian Ministry of Environment for the power generation sector.

13. The notion of energy security – which the IEA defines as uninterrupted availability of energy at an affordable price – encompasses one of the key challenges facing the Indian energy sector. There are different dimensions: access and poverty alleviation (lack of modern energy being the most extreme form of energy insecurity); the quality of energy supply (ability of the system to deliver uninterrupted energy); resilience and flexibility (the ability of the system to react to shocks, disruptions and sudden changes in the supply-demand balance); its diversity (avoiding too great a reliance on a single energy type, supplier or route to market) and affordability. To this one could add the environmental dimension, by including the idea of affordability; the price that India pays for unabated combustion of fossil fuels, although the overlap between energy security and environmental policy objectives is not complete.

standards (MEPS) have been introduced for electric appliances, albeit only 4 out of the 21 current MEPS are mandatory.

As a result of this combination of growing attention to energy efficiency and the rapidly expanding demand for energy, annual investment in energy efficiency rises rapidly in the New Policies Scenario and, even more so, in the Indian Vision Case (Table 4.3). The cumulative investment need of $0.8 trillion in the New Policies Scenario, and $1.5 trillion in the Indian Vision Case, is dominated by energy efficiency investment in transport, followed by buildings and industry.

Table 4.3 ▷ Investment in energy efficiency in the New Policies Scenario and the Indian Vision Case, 2015-2040 ($2014 billion)

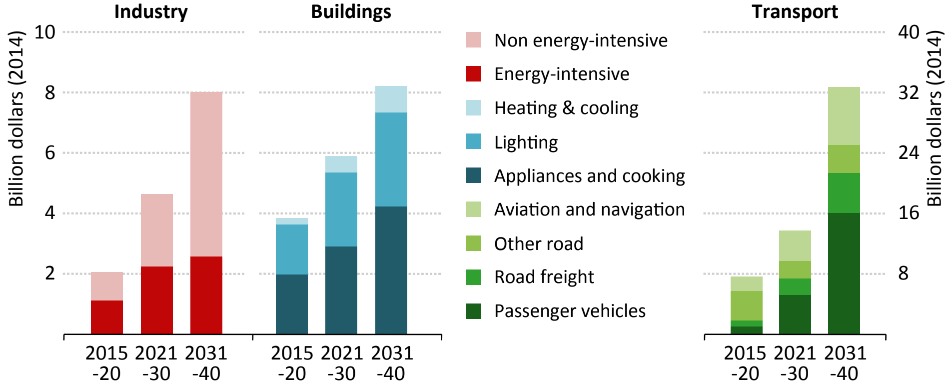
	New Policies Scenario		Indian Vision Case	
	Cumulative	Annual average	Cumulative	Annual average
Industry	139	5	273	10
Energy-intensive	54	2	101	4
Non energy-intensive	85	3	172	7
Buildings	181	7	419	16
Heating and cooling	32	1	73	3
Appliances and cooking	84	3	281	11
Lighting	65	2	66	3
Transport	512	20	802	31
Passenger vehicles	220	8	332	13
Road freight	77	3	238	9
Other road	87	3	100	4
Aviation and navigation	128	5	131	5
Total energy efficiency	**832**	**32**	**1 494**	**57**

Note: The methodology for measuring energy efficiency investment derives from the additional expenditure made by households, firms and the public sector to improve the performance of their energy-using equipment above a baseline of efficiency levels in different end-use sectors in 2014.

As India's transport system has been traditionally dominated by mass transport, today buses account for about half of energy consumption in road transport and are the target for a large share of efficiency spending (part of "other road" transport in Table 4.3 and Figure 4.10). However, in the future, passenger light-duty vehicles (PLDVs) account for the bulk of the increase in energy efficiency spending, as annual PLDV sales increase more than ten-fold to a level of 29 million in 2040. The additional investment to increase energy efficiency in road freight vehicles is substantial in the Indian Vision Case ($161 billion) as tighter fuel-economy standards are included in that case (but not in the New Policies Scenario).[14]

14. As noted, efficiency regulation for freight transport is currently under discussion, but no formal proposal for regulation has yet been announced, so this is not included in the New Policies Scenario.

Figure 4.10 ▷ Average annual investment in energy efficiency by sector in the New Policies Scenario



Note: The volume of efficiency investment in the industry and buildings sectors is on the left axis: the higher volume of investment in transport is indicated on the right axis.

Energy efficiency spending in the buildings sector in the New Policies Scenario is dominated by appliances (representing around 40% of the investment), spending on which becomes more important as incomes and appliance ownership levels rise. Appliance standards are projected to become more stringent and mandatory for a wider range of appliances, including televisions, refrigerators and washing machines. Yet, significant energy efficiency potential for appliances remains unexploited in the New Policies Scenario. Tightening standards further and mobilising an additional cumulative $240 billion in efficiency investment, as in the Indian Vision Case, would exploit this potential and slow energy demand growth. Efficiency spending for lighting also plays an important role, as a consequence of lighting programmes that incentivise a switch from incandescent light bulbs and CFL to LEDs that are becoming more and more efficient (Box 4.4). For heating and cooling, India already has mandatory standards in place for air conditioners. Annual investment in insulation – mainly aimed at reducing energy use for space cooling – reaches a level of $0.4 billion in 2040 in the New Policies Scenario, primarily in commercial and public buildings. In the Indian Vision Case, where building standards become mandatory in all buildings, the required investment level in insulation in 2040 increases by four-times.

Today the majority of the investment in industrial energy efficiency projects is carried out by the energy-intensive industries, particularly chemicals (including fertilisers), steel and cement. The bulk of future spending comes though from less energy-intensive industries, including the brick-making, textiles, food and machinery. Investment is split equally between measures to reduce the need for thermal energy, as in steam systems and industrial furnaces, and those to reduce electricity consumption, mainly in electric motor-driven systems, but also in refrigeration and lighting. In the Indian Vision Case, the focus in terms of industrial efficiency improvements shifts even more to non-energy-intensive industries, where the cumulative investment needs double compared with the New Policies Scenario.

Box 4.4 ▷ Lighting efficiency on a grand scale

Energy Efficiency Services Limited (EESL), a joint venture of various state-owned companies, was set up by India's Ministry of Power as part of the National Mission on Enhanced Energy Efficiency of Power. EESL has several projects underway to promote efficiency in households, public buildings, street lighting and agriculture. The major focus so far has been on lighting, as it represents 10-15% of national electricity consumption and can be reduced by at least half once old inefficient light bulbs have been replaced by LEDs. The level of ambition and the results have both been impressive.

EESL's Street Lighting Programme aims to replace nine million inefficient light bulbs used for street lighting in 240 Indian cities by 2016. No additional investment has to be made by the municipalities because EESL finances the up-front cost and is paid through the financial savings from lower electricity bills. In parallel, EESL is promoting efficient lighting in households by providing 150 million LEDs at the cost of incandescent light bulbs to consumers by March 2016. The higher up-front cost related to energy efficiency, which constitutes one of the main barriers to wider adoption, is financed by EESL and paid back by distribution companies with an annuity over a period of three to ten years.

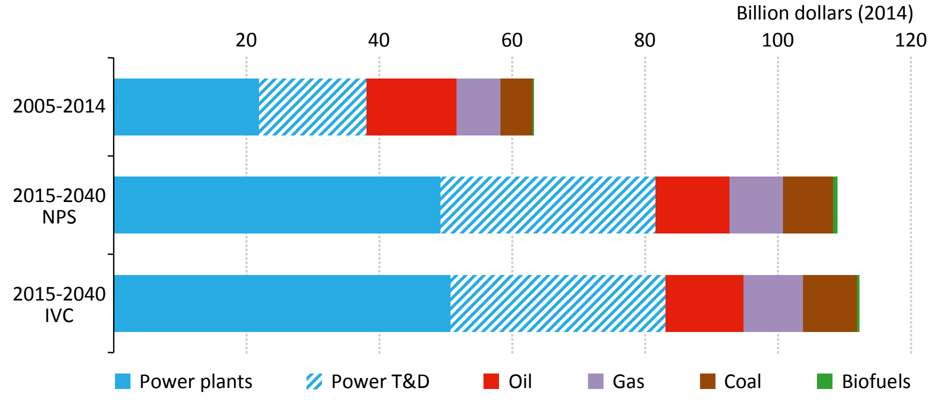
The commitment from EESL to efficient lighting has been a game changer for India's lighting market. The assurance of a stable, large-scale demand for LEDs has led to the build-up of domestic production, driving down the wholesale price paid by EESL for one bulb from more than INR 300 ($4.8) at the start of 2014 to around INR 70 ($1.1) in mid-2015. Similarly the retail price of LED bulbs has been cut to INR 320 ($5.1), significantly lower than European retail prices. Next in line for EESL are initiatives to accelerate the deployment of highly efficient ceiling fans and electric pumps used in agriculture.

Mobilising almost $60 billion in annual investment in end-use energy efficiency represents a huge challenge, with the hurdles taking different forms from sector to sector. Energy-intensive industries are typically among the most aware of opportunities to improve efficiency but the scale of investment, the increasing payback periods and a challenging international environment, e.g. overcapacities in the steel sector, can impede raising capital. The challenges are often higher for smaller companies, for which public loan programmes and knowledge transfer would need to be implemented on a far larger scale than today to provide more information and appropriate financing tools. The situation is similar in the buildings sector, where developers of larger-scale commercial buildings are more familiar with how to realise energy efficiency improvements than those in the larger but more diffuse residential sector. Household spending on energy efficiency in general is relatively small compared with spending on electricity and transport fuels (IEA, 2014a), and poorer households will need significant public assistance such as through the EESL programme or others, in order to realise the required energy savings.

Investment in energy supply

Investment in energy supply in India has risen steadily over the period since 2005 (see Chapter 1), as private capital started flowing to the power sector in particular. But the main scenarios examined here require a further sustained increase in investment flows related to energy supply – a cumulative total of $2.8 trillion over the period to 2040 in the New Policies Scenario and $2.9 trillion in the Indian Vision Case (Figure 4.11 and Table 4.4). The additional energy efficiency investment in the Indian Vision Case is essential to avoid a much larger increase in energy-supply investment in this case.

Figure 4.11 ▷ Average annual investment in energy supply in India in the New Policies Scenario and the Indian Vision Case



Note: NPS = New Policies Scenario; IVC = Indian Vision Case; T&D = transmission and distribution.

The power sector dominates overall investment needs in both cases, with around three-quarters of total investment in energy supply, but there are variations between the two in terms of fuels and technologies. Despite the accelerated push for more costly supercritical coal-fired plants, there is a slight decrease in capital investment in coal-fired capacity in the Indian Vision Case, compared with the New Policies Scenario, as fewer plants are built (and the increased costs of higher-efficiency plants are somewhat contained as the effects of the "Make in India" campaign spread to domestic manufacturing of power plant equipment). Another difference comes in the investment required in renewable energy, notably in solar PV and wind power: investment in the Indian Vision Case in renewable sources of power generation is up by almost 10%, or a cumulative $73 billion over the *Outlook* period, relative to that in the New Policies Scenario. Cumulative installations of solar PV capacity are some 22% higher in the Indian Vision Case. Such a rapid rise in the pace of deployment could strain supply chains and so push up costs, but it would also trigger additional technological learning that helps to keep unit investment costs in check, both those for the domestic manufacturing of solar panels and equipment as well as their installation. The effect of greater technology learning predominates and, as a result, cumulative investment in solar PV is up only 14% in the Indian Vision Case.

Table 4.4 ▷ Investment in energy supply in the New Policies Scenario and the Indian Vision Case, 2015-2040 ($2014 billion)

	New Policies Scenario		Indian Vision Case	
	Cumulative	Annual average	Cumulative	Annual average
Oil	285	11	308	12
Upstream	62	2	82	3
Transport	31	1	34	1
Refining	192	7	192	7
Gas	212	8	234	9
Upstream	127	5	158	6
Transport	84	3	76	3
Coal	199	8	206	8
Mining	127	5	135	5
Transport	72	3	71	3
Power generation	1 277	49	1 322	51
Coal	354	14	330	13
Gas	66	3	64	2
Nuclear	96	4	96	4
Hydro	141	5	137	5
Other renewables	611	23	687	26
of which solar	364	14	412	16
Power transmission and distribution	845	33	838	32
Biofuels	11	0.4	11	0.4
Total energy supply	**2 829**	**109**	**2 919**	**112**

Investment in oil and gas production is higher in the Indian Vision Case, by around 8-10%, as the assumed improvement in conditions and incentives (resulting from a stronger policy push to slow the rise in demand for imports) attract more capital to the upstream sector, particularly into offshore basins. In both cases, investment related to fossil fuels (including upstream, transportation, refining and fossil fuel-fired power plants) accounts for around 40% of the total; renewables around 27%, nuclear just over 3% and biofuels for less than 1%. The remainder covers investment in transmission and distribution.

Investment at this scale certainly cannot be taken for granted in India's complex business environment, presenting a downside risk to our projections (Box 4.5). The power sector is particularly vulnerable to a shortfall in capital: it continues to generate interest from investors, but there is also awareness that the structural weaknesses described in Chapter 2, notably the financial condition of the distribution companies, are unlikely to be resolved quickly. Reducing off-taker risk (i.e. the possibility that generators will not be paid for the electricity sold on to the distribution sector) will be essential if India is to attract capital to the energy sector at the levels required. Investments in each part of the power sector also come with some specific risks: whether coal-fired power plants can rely on the volumes and quality of their coal supply, or to what extent they face the possibility of a future tightening of environmental standards; whether gas-fired plants can remain competitive given their higher fuel costs and whether plants high up in the merit order will be adequately remunerated; whether nuclear or large hydropower plants can secure the necessary permits and authorisations to move ahead; whether investors in non-hydro renewables can feel sufficiently confident in the regulatory framework to put money into capital-intensive technologies; and whether any investment – including in networks – has the degree of local public consent that allows it to go ahead.

Investments in upstream oil and gas likewise face challenges: the most promising of India's remaining hydrocarbon resources are largely offshore, are technically complex to exploit and involve relatively high-cost projects. Whether through adjustments to the fiscal system, to the provisions in upstream contracts, or to the price of the produced product (for natural gas), the policy framework needs to offer potential returns that are commensurate with the risks. In the case of coal, the boost to production will require brownfield projects and new greenfield mines and – although the unit costs of current investments in coal extraction are relatively low – the capital intensity of new projects is set to go up, as mining companies seek to further mechanise their operations, improve safety standards and deploy more advanced technology, especially in underground mining.

Box 4.5 ▷ The risk of a shortfall in power sector investment

There is clear momentum in India behind the drive to modernise the energy system, encompassing cleaner and more reliable energy supply and universal access, and accompanied by the push for better functioning markets. There would be significant downside risk to our projections if this momentum were to wane, or if there were major delays in carrying out planned reforms of the energy market and business environment. An environment in which energy investment falls short of the levels projected in the New Policies Scenario would give rise to important risks to India's economic outlook, as, for example, continued load shedding took its toll on output and productivity: unreliable electricity supply has already been identified by business owners and managers as the second-most important obstacle to business development in India (World Bank Enterprise Survey, 2014).

Prospects for the "Make in India" campaign and the general ambition to re-orientate the economy away from agriculture and services, towards manufacturing industry, would be dealt a heavy blow, as the manufacturing sectors are more energy intensive and rely on affordable and secure supply for their competitiveness. In the absence of reliable grid-based power, companies and households would be forced to rely more on alternatives that are typically more costly, either generating their own power or relying on inverters and batteries that store power from the grid when it is available.

While such solutions can deliver reliable power supply for those who can afford to install them, they are far from optimal from a power system perspective. They are typically more costly than grid-based technologies, in part because they miss out on economies of scale. Replacing a 1 GW coal-fired power plant with five 200 megawatt (MW) captive power plants for large industrial consumers duplicates costs that are not related to the size of the unit, including land acquisition and other permitting issues. Smaller units are also typically less efficient than larger plants, especially if they operate at part load (as is frequently the case since companies often need less electricity than their plants can produce). Fuel spending tends to rise, also because costlier fuels are being used, for example, when 200 diesel generators of 500 kilowatt size each, replace a 100 MW open-cycle turbine fuelled with natural gas, it costs (based on current prices) up to $30 million more per year just for fuel to generate the same amount of electricity.

The emergence by default of a more decentralised power generation system would not necessarily be positive for renewable energy technologies. Rooftop solar PV would get a boost, but utility-scale solar PV and wind power projects – the main route by which India aims to reach its targets for renewables deployment – would suffer. Captive generation plants do not contribute to system security, i.e. they cannot readily be used for balancing purposes, so it would become more difficult to integrate large amounts of variable renewables.

Infrastructure for transportation (not including electricity transmission) and oil refining is another major element in energy-supply investment, of which the largest components are refineries, LNG import terminals and gas pipelines, and coal-related railway infrastructure. Coal-related rail is particularly critical to the adequacy of energy supply. The most pressing railway projects are three lines in Jharkhand (improving the connection of the North Karanpura coal fields), Odisha (improving the connection of the Ib Valley coal fields) and Chhattisgarh (improving connection of the Mand Raigarh and Korba coal fields). There are ongoing discussions about whether railway investments for the carriage of coal can and should be carried out exclusively by the national monopoly, Indian Railways, or whether coal firms or independent private players might invest too. With India becoming the largest importer of coal, investment will be needed in more capital-intensive and longer lead-time port projects.

In the Indian context, the adequacy of investment depends not just on decisions and policies at federal level, but also on the actions of individual states. As things stand, investment flows are far from evenly distributed across India. Taking foreign investment as an example, the top six states – Maharashtra, Delhi, Tamil Nadu, Karnataka, Gujarat and Andhra Pradesh – accounted for over 70% of foreign direct investment flows to India during 2000-2015 (India Department of Industrial Policy and Promotion, 2015).[15] A risk for India in practice is diverging outcomes between states – particularly in the power sector, for which responsibilities are shared between the federal and state levels. The model of competitive

15. In practice the concentration of foreign direct investment may be even higher than this: around a quarter of the total was not allocated by region as it concerned the acquisition of shares by non-residents, operations which may also have involved disproportionately companies in the six states mentioned.

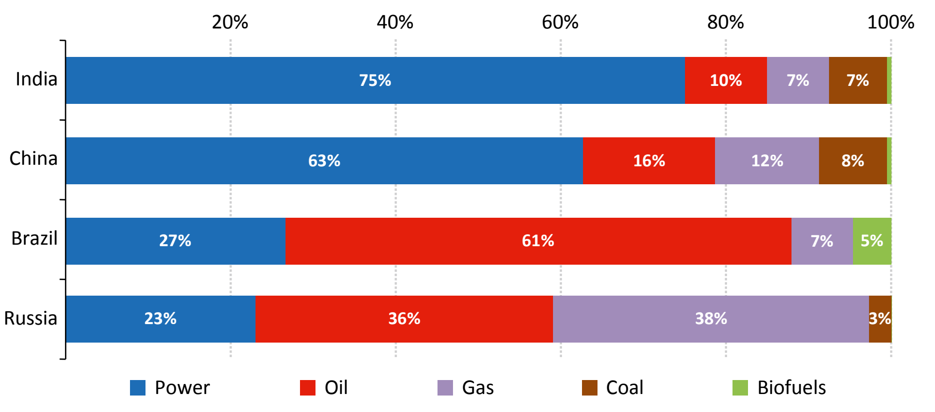
and co-operative federalism, involving a strong dialogue between the states (an area where the National Institution for Transforming India [NITI Aayog] can play a positive role) can stimulate innovative policy experiments at the state level and ensure that successful policy approaches can be easily and quickly studied and emulated across the country.

Well co-ordinated policy-making is essential to ensure that different institutions with responsibilities for various aspects of energy policy avoid operating at cross-purposes and synchronise the delivery of different parts of the system (e.g. new power plants with appropriate grid connections, coal supply with rail and port infrastructure, urban planning with provision for public transport). Integrated policy-making also involves looking at land use, water, biodiversity and protected areas issues, alongside timely engagement with relevant stakeholders at numerous levels – federal, regional, state and local.

Financing

Investment on the scale required will also need to call upon a broader range of investors in Indian energy than has been the case in the past. As the availability of public funds cannot be assumed, due to competing priorities (see Chapter 1), greater private participation in energy infrastructure projects is likely to be required. International investors, too, are likely to play a greater role – and indeed have been invited to lead investments in the renewables sector in support of achieving the 175 GW capacity target by 2022 (some private investors, including Essar and SunEdison, have already been heavily involved in solar projects in Gujarat). These investors and others are attracted by India's size, its growth potential and an auspicious current environment, in which a reforming administration coincides with a lower oil price that eases pressures on public finance and inflation. But the challenges are severe, including a lack of clarity and certainty around the rules of the game, the complexity of administrative procedures and some ambiguous boundary lines between national, state and local competences.

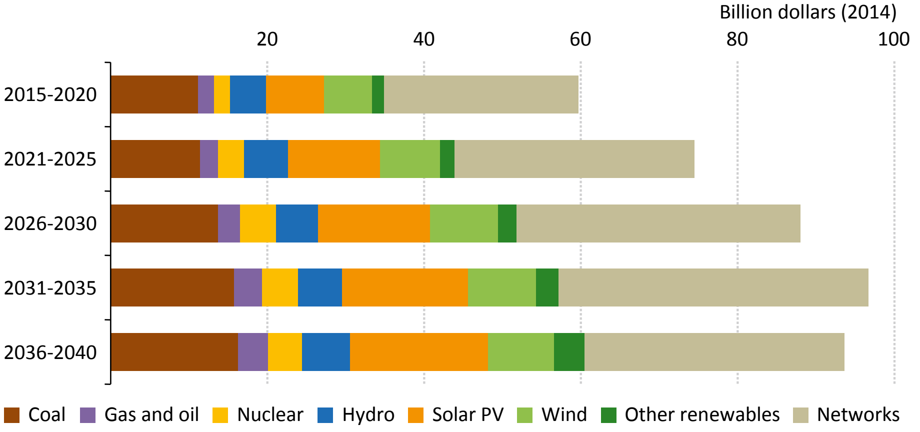
Figure 4.12 ▻ Breakdown of cumulative energy supply investment by sector in selected countries in the New Policies Scenario, 2015-2040



The share of future investment going to the power sector is higher in India than in most other emerging economies – and this will be the key arena in which the adequacy of future investment and of financing will be tested (Figure 4.12). In India (as in many other countries experiencing rapid economic expansion and, indeed, in countries throughout the world), many companies need to borrow to grow; retained earnings are unlikely to be sufficient.[16] This puts the spotlight on three main external sources of capital for financing the power sector: public funds; domestic savings, channelled via the banking system or Indian capital markets; and international capital flows, including development finance.

Up until now, domestic public money and finance from the banking sector, together with some development finance and funding from Chinese equipment manufacturers, has generally proven sufficient for the capital needs of the Indian power sector. But this model looks set to come under increasing strain. Large outlays are foreseen for the energy sector, including low-carbon generation projects, and this, coupled with the host of risks associated with political, regulatory, technological, and financial aspects that affect the bankability of new projects, suggests that these sources will be stretched too thin to provide all the capital needed (Figure 4.13).

Figure 4.13 ▷ Average annual investment in the power sector in India in the New Policies Scenario



A part of the problem is the relatively narrow range of domestic financing options available. There is strong reliance in India on – and preference for – loans from the banking system, rather than capital markets: corporate lending from banks (as opposed to bonds or securitised loans via the capital markets) accounts for well over 90% of external financing (Group of Thirty, 2013). While the Indian capital markets have many listed companies, relatively few are actively traded and tapping these markets for funding is typically an avenue followed only by the very largest Indian companies (Didier and Schmukler, 2013).

16. The *World Energy Investment Outlook* (IEA, 2014b) demonstrated that a higher share of energy investment is financed through retained earnings in OECD markets, but that more debt and equity is needed in non-OECD countries.

However, bank loans are not generally a good match for the long-term needs of energy investment projects. More than 80% of loans outstanding from the Indian banking sector have a maturity of less than five years. The market for corporate bonds – which typically have a longer maturity – is relatively under-developed in India and has a capitalisation of only 5% of GDP, limiting its ability to supply long-term financing (OECD, 2014). There are also banking regulations and guidelines from the Reserve Bank of India that direct credit to various sectors and influence interest rates and the other conditions for lending by banks: a surge in the demand for investment into renewables or other generally more capital-intensive energy technologies might lead to difficulties because of sectoral risk clauses that limit the exposure of lenders to individual sectors.

Recognising these potential vulnerabilities, the Indian government is seeking to broaden the range of financing options available and bring down the cost of long-term finance. This is the purpose, for example, of India's Infrastructure Debt Funds – investment vehicles designed to accelerate the flow of long-term debt into infrastructure projects – and there are other initiatives specifically aimed at attracting finance for low-carbon projects and high efficiency technologies. International financing, theoretically a cheaper source of capital, requires a currency hedge to protect against the risk of devaluation (and market-based currency hedging in India pushes up the cost of debt towards that available on the domestic market). In response, the Indian government has shown interest in providing a government-sponsored currency hedging facility (Climate Policy Initiative, 2015). Such a facility could become very expensive in the event of sharp devaluation in the currency – but a well-designed facility of this kind would address the strategic need to bring cheaper capital at scale to the renewables sector, alongside an enhanced role for low-carbon finance from the multilateral development banks.

Tables for scenario projections

General note to the tables

The tables in this Annex detail India projections to 2040 in the New Policies Scenario (NPS) and the Indian Vision Case (IVC). These tables are in three categories, including:

- Annex A1: Fossil-fuel production and investments in fossil-fuel supply and power.
- Annex A2: Primary energy demand and final consumption.
- Annex A3: Energy access to electricity and clean cooking facilities, gross electricity generation, electrical capacity, and energy-related carbon-dioxide (CO_2) emissions.

Data for fossil-fuel production, energy demand, gross electricity generation and CO_2 emissions from fuel combustion up to 2013 are based on IEA statistics, (*www.iea.org/statistics*) published in *Energy Balances of OECD Countries*, *Energy Balances of non-OECD Countries*, *CO_2 Emissions from Fuel Combustion* and the *IEA Monthly Oil Data Service*. Historical data for gross electrical capacity are drawn from the Platts World Electric Power Plants Database (April 2015 version) and the International Atomic Energy Agency PRIS database (*www.iaea.org/pris*).

Both in the text of this book and in the tables, rounding may lead to minor differences between totals and the sum of their individual components. Growth rates are calculated on a compound average annual basis and are marked "n.a." when the base year is zero or the value exceeds 200%. Nil values are marked "-".

Definitional note to the tables

Total primary energy demand (TPED) is equivalent to power generation plus other energy sector excluding electricity and heat, plus total final consumption (TFC) excluding electricity and heat. TPED does not include ambient heat from heat pumps or electricity trade. Sectors comprising TFC include industry, transport, buildings (residential, services and non-specified other) and other (agriculture and non-energy use). Projected gross electrical capacity is the sum of existing capacity and additions, less retirements.

Total CO_2 includes emissions from other energy sector in addition to the power generation and TFC sectors shown in the tables. CO_2 emissions do not include emissions from industrial waste and non-renewable municipal waste. Using the 2006 IPCC guidelines, instead of the older 1996 guidelines, has led to a change in the definition and absolute levels of CO_2 emissions from fossil-fuel combustion compared with previous *WEO* editions. For more information please visit: *www.iea.org/statistics/topics/CO2emissions.*

New Policies Scenario

	Oil production (mb/d)							Shares (%)		CAAGR (%)
	2000	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total oil	**0.8**	**0.9**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**100**	**100**	**-0.9**
Crude oil	0.6	0.7	0.5	0.4	0.4	0.3	0.3	78	37	-3.5
Natural gas liquids	0.2	0.2	0.2	0.2	0.2	0.3	0.3	18	43	2.4
Unconventional oil	0.0	0.0	0.0	0.1	0.1	0.1	0.1	4	20	4.9

	Natural gas production (bcm)							Shares		CAAGR
	2000	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total natural gas	**28**	**35**	**38**	**45**	**55**	**69**	**89**	**100**	**100**	**3.6**
Conventional gas	28	34	37	38	40	42	45	99	50	1.0
Unconventional gas	-	0	2	7	15	28	44	1	50	19.7

	Coal production (Mtce)							Shares		CAAGR
	2000	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total coal	**187**	**340**	**425**	**514**	**632**	**775**	**926**	**100**	**100**	**3.8**
Steam coal	163	291	368	450	562	697	842	85	91	4.0
Coking coal	16	35	37	40	42	45	47	10	5	1.1
Lignite	8	14	21	24	28	33	37	4	4	3.5

	Average annual investments (billion, year-2014 US dollars)					Cumulative investments	
	2015-20	2021-25	2026-30	2031-35	2036-40	2015-25	2026-40
Oil sector	**7.1**	**7.9**	**9.8**	**13.5**	**17.4**	**81.9**	**203.2**
Upstream	1.9	2.0	2.6	2.8	2.8	21.6	40.7
Transport	0.6	0.7	1.0	1.6	2.1	7.1	23.6
Refining	4.6	5.1	6.2	9.1	12.5	53.1	138.8
Gas sector	**2.9**	**6.6**	**8.2**	**10.0**	**14.1**	**50.1**	**161.5**
Upstream	0.9	3.6	4.8	6.1	9.9	23.2	104.1
Transport	2.0	3.0	3.4	3.8	4.3	26.8	57.4
Coal sector	**6.0**	**5.9**	**7.3**	**9.3**	**10.1**	**65.6**	**133.4**
Mining	3.1	3.6	4.6	6.2	7.2	36.7	90.0
Transport	2.9	2.3	2.7	3.1	2.9	28.9	43.4
Power sector	**59.6**	**74.4**	**88.0**	**96.7**	**93.7**	**729.8**	**1 392.1**
Power plants	35.0	43.8	51.9	57.3	60.5	428.8	847.8
Renewables	19.8	26.7	30.6	33.3	36.0	252.1	499.3
Fossil-fuelled	13.2	13.7	16.7	19.5	20.2	147.7	282.1
T&D	24.6	30.6	36.2	39.4	33.3	301.0	544.3

Indian Vision Case

	Oil production (mb/d)					Difference (IVC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2013-40
Total oil	**0.7**	**0.7**	**0.7**	**0.8**	**0.9**	**0.1**	**0.2**	**100**	**-0.0**
Crude oil	0.5	0.4	0.4	0.4	0.4	0.1	0.1	42	-2.3
Natural gas liquids	0.2	0.2	0.2	0.3	0.4	0.0	0.1	42	3.3
Unconventional oil	0.0	0.1	0.1	0.1	0.1	-0.0	-0.0	16	4.9

	Natural gas production (bcm)					Difference		Shares	CAAGR
	2020	2025	2030	2035	2040	2030	2040	2040	2013-40
Total natural gas	**39**	**46**	**59**	**82**	**116**	**5**	**27**	**100**	**4.6**
Conventional gas	37	39	42	46	51	2	6	44	1.5
Unconventional gas	2	7	17	36	65	2	21	56	21.4

	Coal production (Mtce)					Difference		Shares	CAAGR
	2020	2025	2030	2035	2040	2030	2040	2040	2013-40
Total coal	**474**	**588**	**703**	**829**	**947**	**70**	**22**	**100**	**3.9**
Steam coal	416	523	630	748	861	68	19	91	4.1
Coking coal	37	41	43	46	47	0	-	5	1.1
Lignite	21	25	30	35	39	2	2	4	3.7

	Average annual investments (billion, year-2014 US dollars)					Cumulative investments	
	2015-20	2021-25	2026-30	2031-35	2036-40	2015-25	2026-40
Oil sector	**7.1**	**8.4**	**10.7**	**14.9**	**19.1**	**84.6**	**223.4**
Upstream	1.9	2.5	3.5	4.0	4.1	24.2	58.1
Transport	0.6	0.8	1.1	1.8	2.4	7.3	26.5
Refining	4.6	5.1	6.2	9.1	12.5	53.1	138.8
Gas sector	**2.5**	**6.5**	**8.5**	**11.1**	**17.6**	**47.9**	**185.9**
Upstream	0.9	3.8	5.4	7.6	13.6	24.6	133.1
Transport	1.6	2.7	3.1	3.5	4.0	23.3	52.8
Coal sector	**6.5**	**6.6**	**7.8**	**9.3**	**9.6**	**71.8**	**133.9**
Mining	3.6	4.4	5.0	6.2	7.0	43.9	90.9
Transport	2.9	2.2	2.8	3.1	2.7	28.0	43.1
Power sector	**67.2**	**83.4**	**87.6**	**90.5**	**89.8**	**820.3**	**1 340.0**
Power plants	41.4	51.5	52.0	53.1	58.0	506.0	815.9
Renewables	25.9	34.5	31.8	31.7	35.7	327.8	496.1
Fossil-fuelled	13.6	13.5	15.6	17.0	18.1	149.1	253.2
T&D	25.8	31.9	35.7	37.4	31.8	314.4	524.1

New Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	1990	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
TPED	**308**	**775**	**1 018**	**1 207**	**1 440**	**1 676**	**1 908**	**100**	**100**	**3.4**
Coal	94	341	476	568	690	814	934	44	49	3.8
Oil	63	176	229	273	329	393	458	23	24	3.6
Gas	11	45	58	81	103	126	149	6	8	4.6
Nuclear	2	9	17	28	43	57	70	1	4	7.9
Hydro	6	12	15	19	22	25	29	2	1	3.2
Bioenergy	133	188	209	215	217	213	209	24	11	0.4
Other renewables	0	4	13	23	35	47	60	0	3	11.0
Power sector	**65**	**282**	**393**	**474**	**581**	**693**	**806**	**100**	**100**	**4.0**
Coal	49	223	300	337	397	462	529	79	66	3.3
Oil	5	8	9	10	10	11	11	3	1	1.3
Gas	3	14	18	33	44	57	69	5	9	6.1
Nuclear	2	9	17	28	43	57	70	3	9	7.9
Hydro	6	12	15	19	22	25	29	4	4	3.2
Bioenergy	-	13	22	27	32	37	43	5	5	4.5
Other renewables	0	3	12	21	32	44	55	1	7	11.2
Other energy sector	**23**	**70**	**91**	**112**	**137**	**161**	**183**	**100**	**100**	**3.6**
Electricity	*7*	*27*	*37*	*44*	*54*	*64*	*74*	*38*	*40*	*3.9*
TFC	**245**	**527**	**686**	**815**	**968**	**1 122**	**1 275**	**100**	**100**	**3.3**
Coal	39	103	151	194	242	289	333	20	26	4.4
Oil	52	150	202	243	298	360	423	28	33	3.9
Gas	6	25	35	43	53	62	71	5	6	4.0
Electricity	18	77	115	150	192	236	281	15	22	4.9
Bioenergy	130	171	182	183	180	171	161	33	13	-0.2
Other renewables	0	0	1	2	2	4	5	0	0	9.1
Industry	**69**	**185**	**263**	**336**	**417**	**497**	**572**	**100**	**100**	**4.3**
Coal	27	91	137	180	228	277	322	49	56	4.8
Oil	10	19	24	29	34	40	45	10	8	3.3
Gas	1	13	18	23	28	32	35	7	6	3.9
Electricity	9	32	49	62	78	94	110	17	19	4.6
Bioenergy	23	30	36	42	48	54	59	16	10	2.5
Other renewables	0	0	0	0	1	1	2	0	0	16.2
Transport	**21**	**75**	**108**	**136**	**176**	**224**	**280**	**100**	**100**	**5.0**
Oil	18	72	104	130	166	210	258	96	92	4.9
Electricity	0	1	2	2	2	2	3	2	1	2.5
Biofuels	-	0	1	1	3	5	8	0	3	16.0
Other fuels	2	1	2	3	5	7	10	2	4	7.5
Buildings	**134**	**214**	**242**	**257**	**274**	**287**	**299**	**100**	**100**	**1.2**
Coal	10	13	14	14	14	13	11	6	4	-0.5
Oil	11	27	31	33	38	43	47	13	16	2.1
Gas	0	4	5	5	6	8	9	2	3	3.2
Electricity	5	29	46	62	84	109	135	14	45	5.8
Bioenergy	108	141	146	140	130	112	94	66	31	-1.5
Other renewables	0	0	1	1	2	2	3	0	1	7.7
Other	**22**	**53**	**71**	**86**	**101**	**113**	**123**	**100**	**100**	**3.2**

Indian Vision Case

	Energy demand (Mtoe)					Difference (IVC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2013-40
TPED	**1 029**	**1 238**	**1 482**	**1 712**	**1 930**	**43**	**22**	**100**	**3.4**
Coal	481	578	704	819	922	13	- 11	48	3.7
Oil	237	292	355	419	483	26	25	25	3.8
Gas	58	82	104	127	151	1	3	8	4.6
Nuclear	17	28	43	57	70	-	-	4	7.9
Hydro	15	19	22	25	28	0	- 0	1	3.1
Bioenergy	205	209	212	209	203	- 5	- 6	10	0.3
Other renewables	16	29	42	56	73	7	13	4	11.8
Power sector	**393**	**472**	**573**	**670**	**768**	**- 7**	**- 38**	**100**	**3.8**
Coal	297	327	382	435	488	- 15	- 41	63	2.9
Oil	9	11	12	10	9	1	- 2	1	0.6
Gas	18	34	45	56	66	1	- 2	9	6.0
Nuclear	17	28	43	57	70	-	-	9	7.9
Hydro	15	19	22	25	28	0	- 0	4	3.1
Bioenergy	22	27	32	37	42	0	- 0	6	4.5
Other renewables	14	27	39	51	64	6	9	8	11.8
Other energy sector	**92**	**113**	**140**	**163**	**185**	**3**	**2**	**100**	**3.7**
Electricity	*37*	*44*	*54*	*63*	*72*	*0*	*- 2*	*39*	*3.8*
TFC	**699**	**850**	**1 017**	**1 176**	**1 326**	**49**	**51**	**100**	**3.5**
Coal	158	212	269	319	361	27	28	27	4.7
Oil	209	262	323	387	450	25	27	34	4.1
Gas	34	43	53	63	75	0	4	6	4.2
Electricity	117	153	194	235	277	2	- 5	21	4.9
Bioenergy	179	177	175	167	155	- 5	- 6	12	-0.4
Other renewables	1	2	3	5	9	1	4	1	11.6
Industry	**275**	**365**	**457**	**542**	**614**	**40**	**41**	**100**	**4.5**
Coal	144	198	255	307	350	27	28	57	5.1
Oil	25	31	37	43	47	3	2	8	3.5
Gas	18	23	27	31	33	- 1	- 2	5	3.6
Electricity	50	66	82	99	114	5	5	19	4.8
Bioenergy	39	47	55	61	64	7	6	11	2.8
Other renewables	0	0	1	2	5	0	3	1	21.1
Transport	**113**	**147**	**189**	**237**	**292**	**13**	**12**	**100**	**5.2**
Oil	108	141	179	222	268	13	9	92	5.0
Electricity	2	2	2	2	3	0	0	1	2.5
Biofuels	1	1	2	4	6	- 0	- 2	2	14.9
Other fuels	2	3	5	8	15	- 0	4	5	8.8
Buildings	**237**	**245**	**260**	**270**	**279**	**- 14**	**- 20**	**100**	**1.0**
Coal	15	14	14	12	11	- 0	- 0	4	-0.6
Oil	32	34	40	46	51	2	4	18	2.4
Gas	5	6	7	9	10	1	1	4	3.5
Electricity	46	60	79	98	119	- 5	- 15	43	5.3
Bioenergy	140	129	118	102	84	- 12	- 10	30	-1.9
Other renewables	1	2	2	3	4	0	1	1	8.6
Other	**74**	**93**	**111**	**128**	**141**	**11**	**18**	**100**	**3.7**

New Policies Scenario

Without access to:	Energy access (million) 2013	2020	2025	2030	2035	2040	Share of population (%) 2013	2040
Electricity	237	157	113	63	33	-	19	-
Clean cooking facilities	841	832	785	707	595	481	67	30

	Electricity generation (TWh)							Shares (%)		CAAGR (%)
	1990	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total generation	**293**	**1 193**	**1 766**	**2 251**	**2 848**	**3 485**	**4 124**	**100**	**100**	**4.7**
Coal	192	869	1 224	1 412	1 698	2 009	2 333	73	57	3.7
Oil	13	23	26	29	32	36	37	2	1	1.7
Gas	10	65	96	185	262	348	431	5	10	7.3
Nuclear	6	34	66	109	165	218	269	3	7	7.9
Hydro	72	142	174	215	253	293	333	12	8	3.2
Bioenergy	-	23	48	64	80	99	121	2	3	6.3
Solar PV	-	3	40	90	152	218	285	0	7	17.8
Other renewables	0	34	93	148	207	264	316	3	8	8.7

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total capacity	**263**	**436**	**583**	**746**	**916**	**1 076**	**100**	**100**	**5.4**
Coal	154	230	276	329	385	438	59	41	3.9
Oil	7	9	11	13	15	15	3	1	2.8
Gas	22	41	57	76	100	122	8	11	6.6
Nuclear	6	10	16	24	31	39	2	4	7.3
Hydro	43	58	71	83	95	108	16	10	3.5
Bioenergy	7	10	13	16	20	24	3	2	4.6
Solar PV	3	28	61	100	142	182	1	17	16.8
Other renewables	21	51	78	104	128	148	8	14	7.5

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	1990	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total CO_2	**534**	**1 880**	**2 569**	**3 081**	**3 744**	**4 445**	**5 147**	**100**	**100**	**3.8**
Coal	370	1 348	1 870	2 218	2 682	3 156	3 623	72	70	3.7
Oil	151	447	585	697	850	1 027	1 213	24	24	3.8
Gas	13	85	115	166	212	263	311	5	6	4.9
Power sector	**218**	**943**	**1 262**	**1 445**	**1 715**	**2 006**	**2 300**	**100**	**100**	**3.4**
Coal	194	886	1 192	1 339	1 579	1 837	2 103	94	91	3.3
Oil	16	25	27	30	33	35	36	3	2	1.3
Gas	8	32	43	77	104	134	162	3	7	6.1
TFC	**300**	**894**	**1 257**	**1 581**	**1 969**	**2 372**	**2 770**	**100**	**100**	**4.3**
Coal	170	460	673	873	1 095	1 310	1 511	51	55	4.5
Oil	128	391	525	633	780	950	1 130	44	41	4.0
Transport	*56*	*219*	*316*	*395*	*506*	*640*	*787*	*24*	*28*	*4.9*
Gas	2	43	59	75	94	112	130	5	5	4.2

Indian Vision Case

Without access to:	Energy access 2020	2025	2030	2035	2040	Difference (IVC minus NPS) 2030	2040	Share of population (%) 2040
Electricity	106	-	-	-	-	-63	-	-
Clean cooking facilities	795	714	632	526	410	-75	-71	26

	Electricity generation (TWh)					Difference (IVC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2013-40
Total generation	**1 788**	**2 294**	**2 877**	**3 456**	**4 049**	**28**	**-74**	**100**	**4.6**
Coal	1 213	1 377	1 645	1 912	2 185	-53	-148	54	3.5
Oil	27	33	36	32	30	4	-6	1	1.0
Gas	96	190	262	337	414	1	-17	10	7.1
Nuclear	66	109	165	218	269	-	-	7	7.9
Hydro	174	216	254	291	328	1	-5	8	3.2
Bioenergy	48	64	81	99	118	0	-2	3	6.2
Solar PV	69	152	218	284	345	67	60	9	18.6
Other renewables	94	153	216	284	360	9	44	9	9.2

	Electrical capacity (GW)					Difference (IVC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2013-40
Total capacity	**460**	**633**	**799**	**958**	**1 111**	**53**	**35**	**100**	**5.5**
Coal	232	277	328	379	428	-1	-10	39	3.8
Oil	10	13	14	13	13	1	-3	1	2.1
Gas	40	60	80	100	121	4	-1	11	6.6
Nuclear	10	16	24	31	39	-	-	3	7.3
Hydro	58	71	83	95	107	0	-1	10	3.4
Bioenergy	10	14	17	20	23	0	-1	2	4.5
Solar PV	48	103	145	185	221	45	39	20	17.6
Other renewables	51	80	108	134	160	3	12	14	7.8

	CO_2 emissions (Mt)					Difference (IVC minus NPS)		Shares (%)	CAAGR (%)
	2020	2025	2030	2035	2040	2030	2040	2040	2013-40
Total CO_2	**2 610**	**3 175**	**3 865**	**4 525**	**5 157**	**121**	**10**	**100**	**3.8**
Coal	1 889	2 259	2 738	3 179	3 581	56	-42	69	3.7
Oil	608	749	914	1 085	1 261	64	48	24	3.9
Gas	114	167	213	261	315	1	4	6	5.0
Power sector	**1 250**	**1 413**	**1 659**	**1 890**	**2 124**	**-57**	**-177**	**100**	**3.1**
Coal	1 179	1 300	1 517	1 727	1 938	-61	-165	91	2.9
Oil	28	34	36	32	29	3	-6	1	0.6
Gas	43	79	105	131	156	1	-6	7	6.0
TFC	**1 310**	**1 708**	**2 146**	**2 567**	**2 953**	**177**	**183**	**100**	**4.5**
Coal	705	953	1 213	1 443	1 632	117	122	55	4.8
Oil	546	680	840	1 012	1 184	61	54	40	4.2
Transport	*330*	*428*	*546*	*677*	*816*	*40*	*29*	*28*	*5.0*
Gas	58	74	93	113	137	-1	7	5	4.4

Definitions

This annex provides general information on terminology used throughout the report including: units; general conversion factors; and definitions.

Units

Coal	Mtce	million tonnes of coal equivalent
Energy	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	mcm	million cubic metres
	bcm	billion cubic metres
	tcm	trillion cubic metres
Mass	kg	kilogramme (1 000 kg = 1 tonne)
	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)
Monetary	$ million	1 US dollar x 10^6
	$ billion	1 US dollar x 10^9
	$ trillion	1 US dollar x 10^{12}
Oil	b/d	barrels per day
	kb/d	thousand barrels per day
	mb/d	million barrels per day
Power	W	watt (1 joule per second)
	kW	kilowatt (1 Watt x 10^3)
	MW	megawatt (1 Watt x 10^6)
	GW	gigawatt (1 Watt x 10^9)
	TW	terawatt (1 Watt x 10^{12})

Energy conversions

Convert to:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11 630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3 412	1

Currency conversions

Exchange rates *(2014 annual average)*	**1 US Dollar equals:**
British Pound	0.61
Chinese Yuan	6.14
Euro	0.75
Indian Rupee	61.74
Japanese Yen	105.69

Definitions

Back-up generation capacity

Households and businesses connected to the main power grid may also have some form of "back-up" power generation capacity that can, in the event of disruption, provide electricity. Back-up generators are typically fuelled with diesel or gasoline and capacity can be from as little as a few kilowatts. Such capacity is distinct from mini- and off-grid systems that are not connected to the main power grid.

Bioenergy

Refers to the energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. It includes solid biomass, biofuels and biogas.

Biofuels

Biofuels are liquid fuels derived from biomass or waste feedstocks and include ethanol and biodiesel. They can be classified as conventional and advanced biofuels according to the technologies used to produce them and their respective maturity.

Biogas

A mixture of methane and carbon dioxide produced by bacterial degradation of organic matter and used as a fuel.

Clean cooking facilities

Cooking facilities that are considered safer, more efficient and more environmentally sustainable than the traditional facilities that make use of solid biomass (such as a three-stone fire). This refers primarily to improved solid biomass cookstoves, biogas systems, liquefied petroleum gas stoves, ethanol and solar stoves.

Investment for access to clean cooking facilities

Investment for access to clean cooking facilities includes financing for improved biomass cookstoves and in stoves using cleaner fuels such as liquefied petroleum gas, biogas and solar stoves.

Investment for access to electricity

Investment for access to electricity includes finance for new transmission and distribution lines, new power generation capacity in mini- and off-grid systems, as well as the share of capacity additions connected to the main grid needed to meet access-related electricity demand.

Investment for energy-efficiency

Investment in energy efficiency is defined as the additional expenditure made by households, firms and the public sector to improve the performance of energy-using equipment above the average efficiency level of that equipment in 2014. Estimates of investment needs have been made across sub-sectors in industry, across modes in transport and across end-uses in buildings.

Investment on the supply-side

All investment data and projections reflect "overnight investment", i.e. the capital spent is generally assigned to the year production (or trade) is started, rather than the year when it actually incurs. Investments for oil, gas, and coal include production, transformation and transportation; those for the power sector include refurbishments, uprates, new builds and replacements for all fuels and technologies for on-grid, mini-grid and off-grid generation, as well as investment in transmission and distribution. Investment data are presented in real terms in year-2014 US dollars.

Mini-grids

Small grid systems linking a number of households and other consumers.

Modern energy access

Access to modern energy services includes household access to a minimum level of electricity; household access to safer and more sustainable cooking and heating fuels and stoves; access that enables productive economic activity; and access for public services.

Modern use of solid biomass

Modern use of solid biomass refers to the use of solid biomass in improved cookstoves and modern technologies using processed biomass such as pellets.

Off-grid systems

Stand-alone systems for individual households or groups of consumers.

Solid biomass

Solid biomass includes charcoal, fuelwood, dung, agricultural residues, wood waste and other solid wastes.

Traditional use of solid biomass

The traditional use of solid biomass refers to the use of solid biomass with basic technologies, such as a three-stone fire, often with no or poorly operating chimneys.

References

Chapter 1: Energy in India today

Anand, R. (2013), *The Fiscal and Welfare Impacts of Reforming Fuel Subsidies in India*, International Monetary Fund, Washington, DC.

CEA (Central Electricity Authority) (2014a), *General Review 2014*, CEA, New Delhi.

– (2014b), *Monthly Generation Report, www.cea.nic.in/reports/monthly/generation_rep/actual/dec14/actual-dec14.html*, accessed 12 October 2015.

Chaturvedi, V., et al. (2014), *State of Environmental Clearances in India: Procedures, Timelines and Delays across Sectors and States*, Council on Energy, Environment and Water, New Delhi.

CSO (Central Statistics Office) (2015), *Energy Statistics 2015*, CSO, New Delhi.

DAE (Department of Atomic Energy) (2015), *Annual Report 2014-15*, DAE, Mumbai.

FICCI (Federation of Indian Chambers of Commerce & Industry) (2012), *Lack of Affordable & Quality Power: Shackling India's Growth Story*, FICCI, New Delhi.

IEA (International Energy Agency) (2012), *Understanding Energy Challenges in India: Policies, Players and Issues*, OECD/IEA, Paris.

– (2015), *World Energy Outlook 2015*, OECD/IEA, Paris.

IMF (International Monetary Fund) (2015), *2015 Article IV Consultation – Staff Report*, IMF, Washington, DC.

Jain, A., et al. (2015), *Access to Clean Cooking Energy and Electricity – Survey of States*, Council on Energy, Environment and Water, New Dehli.

MNRE (Ministry of New and Renewable Energy) (2015), *Small Hydro*, *http://mnre.gov.in/schemes/grid-connected/small-hydro/*, accessed 12 October 2015.

Ministry of Statistics and Programme Implementation (2012), *National Sample Survey Office, Household Consumption of Various Goods and Services in India*, Government of India, New Delhi.

National Sample Survey Office (2014a), *Household Consumption of Various Goods and Services in India 2011-2012*, Government of India, New Delhi.

– (2014b), *Urban Slums in India, 2012,* Government of India, New Delhi.

OECD (Organisation for Economic Co-operation and Development) (2014), *Economic Survey of India*, OECD, Paris.

Pargal, S. and S. Ghosh Banerjee (2014), *More Power to India: The Challenge of Electricity Distribution*, World Bank, Washington, DC.

Petroleum Planning and Analysis Cell (2015), *http://ppac.org.in/content/212_1_Import Export.aspx*, accessed 4 October 2015.

Power Finance Corporation (2014), *The Performance of State Power Utilities for the years 2010/11 to 2012/13*, Power Finance Corporation, Mumbai.

TERI (The Energy Research Institute) (2015), *Policy Brief. Crisis in India's Electricity Distribution Sector: Time to Reboot for a Viable Future*, TERI, New Delhi.

UNICEF (United Nations Children's Fund) (2012), *The State of the World's Children 2012*, UNICEF, New York.

UNCTAD (United Nations Conference on Trade and Development) (2015), *World Investment Report*, UNCTAD, Geneva.

United Nations Population Division (UNPD) (2015), *World Population Prospects: The 2015 Revision*, United Nations, New York.

World Bank (2014), *Brief: The Transport Sector in India*, *http://go.worldbank.org/FUE8JM6E40*, accessed 4 October 2015.

World Health Organization (WHO) (2014), Ambient Air Pollution Database, WHO, Geneva.

WRI (World Resources Institute) (2014), "Identifying the Global Coal Industry's Water Risks", WRI, Washington, DC.

Chapter 2: Outlook for India's energy consumption

Airbus (2015), Market Forecast, *www.airbus.com/company/market/forecast/*, accessed 27 July 2015.

BP (2015), *BP Statistical Review of World Energy 2015*, BP, London.

CDKN (Climate & Development Knowledge Network) (2013), *Creating Market Support for Energy Efficiency: India's Perform, Achieve and Trade Scheme*, CDKN, London.

Chaturvedi, V. and M. Sharma (2015), "Modelling Long-term HFC Emissions from India's Residential Air-Conditioning Sector: Exploring Implications of Alternative Refrigerants, Best Practices, and A Sustainable Lifestyle within an Integrated Assessment Modelling Framework", *Climate Policy*, Vol. 9.

Department of Fertilizers (2014), *India Fertilizer Scenario 2013*, Government of India, Ministry of Chemicals and Fertilizers, Department of Fertilizers, New Delhi.

Department of Fertilizers (2015), *Annual Report 2014-15 Towards Sustainable and Shared Prosperity*, Government of India, Ministry of Chemicals and Fertilizers, Department of Fertilizers, New Delhi.

Ghosh, A., & Agrawal, S. (2015, August 17), "Sustainable solar irrigation", *Business Standard*, *www.business-standard.com/article/opinion/arunabha-ghosh-shalu-agrawal-sustainable-solar-irrigation-115081701282_1.html*, accessed 4 October 2015.

Government of India, GEF, UNDP (2012), *GEF-UNDP-MoEF Project 3465 - Energy Efficiency Improvements in Indian Brick Industry Project*, United Nations Development Programme.

Gulati, A. and P. Banerjee (2015), *Rationalising Fertiliser Subsidy in India: Key Issues and Policy Options*, Indian Council for Research on International Economic Relations, New Delhi.

IEA (International Energy Agency) (2007), *Tracking Industrial Energy Efficiency and CO_2 Emissions*, OECD/IEA, Paris.

– (2015), *World Energy Outlook 2015*, OECD/IEA, Paris.

JPC (Joint Plant Committee) (2014), *Annual Statistics 2013/14*, JPC, Kolkata, India.

Lalchandani, D. and S.Maithel (2013), *Towards Cleaner Brick Kilns in India*, Greentech Knowledge Solutions Private Limited, Chennai, India.

Maithel, S. (2013), *Evaluating Energy Conservation Potential of Brick Production in India*, SAARC (South Asian Association for Regional Cooperation), New Delhi.

Ministry of Agriculture (2013), *State of Indian Agriculture 2012-13*, Government of India. Department of Agriculture and Cooperation, New Delhi.

Ministry of Petroleum & Natural Gas (2014), *Indian Petroleum and Natural Gas Statistics*, Government of India, Ministry of Petroleum & Natural Gas, Economics and Statistics Division, New Delhi.

Nand, S. and M. Goswami (2008), "Recent Efforts in Energy Conservation in Ammonia and Urea Plants", *Indian Journal of Fertilisers,* Vol. 4(12), pp.17-20.

Phadke, A., Abhyankar, N., & Shahh, N. (2014), *Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges,* Berkeley, Lawrence Berkeley National Laboratory.

Palit, B. (2014), "Indian Approaches to Energy Access" in *Energy Poverty*, Oxford University Press, Oxford.

Practical Action (2015), *Gender and Livelihoods Impacts of Clean Cookstoves in South Asia,* Global Alliance for Clean Cookstoves (GACC).

SME Chamber of India (Small and Medium Business Development Chamber of India) (2015), "About MSMEs in India", *www.smechamberofindia.com/about_msmes.aspx*, accessed 28 September 2015.

Shrimali, G., Slaski, X., Thurber, M., & Zerriffi, H. (2011), Improved stoves in India: A study of sustainable business models, *Energy Policy*, 7543-7566.

TERI (The Energy and Resources Institute) (2015), *Energy Security Outlook: Defining a Secure and Sustainable Energy Future for India*, TERI, New Delhi.

USGS (United States Geological Survey) (2012a), "Assessment of Potential Additions to Conventional Oil and Gas Resources of the World (Outside the United States) from Reserve Growth", *Fact Sheet 2012-3052*, USGS, Boulder, Colorado.

– (2012b) "An Estimate of Undiscovered Conventional Oil and Gas Resources of the World", *Fact Sheet 2012-3042*, USGS, Boulder, Colorado.

Chapter 3: Outlook for India's energy supply

BGR (German Federal Institute for Geosciences and Natural Resources) (2014), *Energiestudie 2014, Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen* (Energy Resources 2014, Reserves, Resources and Availability of Energy Resources), BGR, Hannover, Germany.

CEA (Central Electricity Authority) (2014), *Status of Hydro Electric Projects under Execution for 12th Plan & Beyond*, *http://cea.nic.in/reports/proj_mon/status_he_execution.pdf*, accessed 15 September 2015.

Coal Directory of India (2014), *Coal Statistics 2013-14*, Government of India, Ministry of Coal, Coal Controller's Organisation, Kolkata *http://coal.nic.in/sites/upload_files/coal/files/coalupload/coaldir13-14.pdf*, accessed 15 September 2015.

IAEA/OECD (International Atomic Energy Agency and Organisation for Economic Co-operation and Development) (2014), *Uranium 2014: Resources, Production and Demand (The Red Book)*, OECD, Paris.

IEA (International Energy Agency) (2013), *World Energy Outlook 2013*, OECD/IEA, Paris.

– (2014), *World Energy Outlook 2014*, OECD/IEA, Paris.

– (2015), *World Energy Outlook 2015*, OECD/IEA, Paris.

Inventory of Coal Resources of India (2015), *www.cmpdi.co.in/coalinventory.php*, accessed 15, September, 2015.

National Institute of Solar Energy (2014), State-wise Estimated Solar Power Potential in the Country, *http://mnre.gov.in/file-manager/UserFiles/Statewise-Solar-Potential-NISE.pdf*, accessed 9 October 2015.

National Institute of Wind Energy (2015), Wind Resource Assessment, *http://niwe.res.in/department_wra.php*, accessed 9 October 2015.

Chapter 4: Implications of India's energy development

Beinhocker, E. (2007), *Tracking the Growth of India's Middle Class*, McKinsey&Company.

Climate Policy Initiative, "Reaching India's Renewable Energy Targets Cost-Effectively: A Foreign Exchange Hedging Facility; Climate Policy Initiative", accessed 15 October 2015.

Council on Energy, Environment and Water and Natural Resources Defense Council (2014), *Creating Green Jobs: Employment Generation by Gamesa-Renew Power's 85 megawatt wind project in Jath, Maharashtra*, New York and New Delhi.

Didier, T., and Schmukler, S. (2013), “The Financing and Growth of Firms in China and India: Evidence from Capital Markets”, *Journal of International Money and Finance*, Elsevier, Vol. 39.

Dubash, N., et al. (2015), *Informing India’s Energy and Climate Debate: Policy Lessons from Modelling Studies*, Centre for Policy Research, New Delhi.

Government of India (2012), *Census of India 2011: Houses, Households Amenities and Assets*, New Delhi.

Group of Thirty (2013), *Long-term Finance and Economic Growth*, Group of Thirty, Washington, DC.

Hijoka, Y., et al. (2014), *Climate Change 2014: Impacts Adaptation, and Vulnerability*, Cambridge University Press, Cambridge.

IEA (International Energy Agency) (2012), *World Energy Outlook 2012*, OECD/IEA, Paris.

– (2014a) *World Energy Outlook 2014*, OECD/IEA, Paris.

– (2014b), *World Energy Investment Outlook*, OECD/IEA, Paris.

– (2015) *Energy and Climate Change: World Energy Outlook Special Report,* OECD/IEA, Paris.

India Department of Industrial Policy and Promotion (2015), “Fact Sheet on Foreign Direct Investiment (FDI): From April, 2000 to June, 2015”, *www.dipp.nic.in/English/publications/FDI_statistics/2015/india_FDI_June2015.pdf*, accessed 20 October 2015.

Ministry of Labour and Employment (2013), *Pocket Book of Labour Statistics 2013*, Government of India, Shimla/Chandigarh

OECD (Organisation for Economic Co-operation and Development) (2014), *Economic Survey of India*, OECD, Paris.

REN21 (2015), *Renewables 2015 Global Status Report*, REN21 Secretariat, Paris.

Rutovitz (2012), *Calculating Global Energy Sector Jobs: 2012 Methodology*, Institute of Sustainable Futures, University of Technology Sydney, Australia.

World Bank (2014), Enterprise Surveys, World Bank Enterprise Surveys, *www.enterprisesurveys.org/data/exploreeconomies/2014/india*, accessed 20 October 2015.

WWAP (United Nations World Water Assessment Programme) (2014), *The United Nations World Water Development Report 2014: Water and Energy*, UNESCO, Paris.

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