India 2020

Energy Policy Review

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Foreword

India’s achievements in the energy sector in recent years have been outstanding. Led by Prime Minister Shri Narendra Modi and his ministers, the Government of India is implementing reforms towards a secure, affordable and sustainable energy system to power a robust economic growth.

The country has made huge strides to ensure full access to electricity, bringing power to more than 700 million people since 2000. It is pursuing a very ambitious deployment of renewable energy, notably solar, and has boosted energy efficiency through innovative programmes such as replacing incandescent light bulbs with LEDs (under the Ujala scheme). And it is addressing the serious health problems caused by air pollution for its major cities, providing 80 million households with liquefied petroleum gas connection (under the Pradhan Mantri Ujjwala Yojana scheme), thereby reducing the exposure from biomass cooking stoves, a major cause of respiratory diseases.

India is also introducing important energy pricing reforms in the coal, oil, gas, and electricity sectors which are fundamental to further opening the energy market and improving its financial health. It is taking significant steps to enhance its energy security by fostering domestic production through the most significant upstream reform of India's Hydrocarbon Exploration and Licensing Policy (HELP) and building up dedicated oil emergency stocks in the form of a strategic petroleum reserve. The scale of these achievements is hard to overstate.

Building on co-operation that goes back to 1998, India joined the IEA family in March 2017 when it became an Association member, a major milestone in our bilateral collaboration. This relationship has flourished since then with co-operation across all energy sector-related ministries. The IEA benefits greatly from this partnership given India’s importance in global energy markets and the remarkable insights it provides to other IEA members.

The IEA has been conducting in-depth peer reviews of its member countries’ energy policies since 1976. As the IEA opens its doors to emerging economies, our in-depth policy review process is playing a bigger role in our bilateral collaboration with Association countries, and draws upon the unique expertise of the IEA family at large. In January 2019, a team of senior international energy experts visited India to discuss the challenges and opportunities of India’s energy sector with stakeholders from government, industry and academia. This report is the product of those discussions and intensive exchanges between the IEA, the review team and the Indian government throughout the year. This review for India provides a crosscutting overview of India’s energy policy and real-world policy advice and makes recommendations for all areas of India’s energy sector.

I would like to thank the Government of India, notably NITI Aayog CEO Mr Amitabh Kant and his team for the excellent collaboration on this project. My gratitude goes to Ambassador Noé van Hulst from the Netherlands, for leading this review, and to the peers from Canada, Sweden, Switzerland, the United Kingdom, the United States and the European Commission.

Reports like this in-depth review highlight India's excellent achievements and best practices, while at the same time guiding India in its ambitious energy transition, supporting energy policy development, and learning from international experience. I look forward to working even more closely with the Government of India and supporting them in taking their energy policy forward.

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1. Executive summary

With a population of 1.4 billion and one of the world's fastest-growing major economies, India will be vital for the future of the global energy markets. The Government of India has made impressive progress in recent years in increasing citizens' access to electricity and clean cooking. It has also successfully implemented a range of energy market reforms and carried out a huge amount of renewable electricity deployment, notably in solar energy.

Looking ahead, the government has laid out an ambitious vision to bring secure, affordable and sustainable energy to all its citizens. This in-depth review aims to assist the government in meeting its energy policy objectives by setting out a range of recommendations in each area, with a focus on energy system transformation, energy security and energy affordability. The review also highlights a number of important lessons from the rapid development of India's energy sector that could help inform the plans of other countries around the world.

India is making great strides towards affordable, secure and cleaner energy

Ensuring Indian citizens have access to electricity and clean cooking has been at the top of the country's political agenda. Around 750 million people in India gained access to electricity between 2000 and 2019, reflecting strong and effective policy implementation. The IEA highly commends the Government of India for this outstanding result and supports its efforts to shift the focus towards reaching isolated areas and ensuring round-the-clock reliability of electricity supply.

The government of India has also made significant progress in reducing the use of traditional biomass in cooking, the chief cause of indoor air pollution that particularly affects women and children. The government has encouraged clean cooking with liquefied petroleum gas. India continues to promote cleaner cooking and off-grid electrification solutions, including a shift toward using solar photovoltaics (PV) for cooking and charging batteries.

Major energy reforms lead to greater efficiency

The IEA commends India for its continuous pursuit of market opening and greater use of market-based solutions through ambitious energy sector reforms. Increased access to affordable energy has raised the living standards of all segments of the population.

India now has the institutional framework it needs to attract more investment for its growing energy needs. The IEA welcomes the government's decisions to allow private-sector investment in coal mining, and to open up the country's oil and gas retail markets. The creation of functioning energy markets will ensure economic efficiency in the management of the coal, gas and power sectors, which is critical to achieving energy security and supporting the country's economic growth. This will be increasingly important in the future, as energy demand and investment needs increase in line with India's economic expansion.

Reform of India's electricity sector will need to be comprehensive to achieve these goals. The IEA welcomes the reforms proposed by the Central Energy Regulatory Commission (CERC) and progress made towards improved real-time markets. A country-wide wholesale market is very much needed as a backbone for the national grid. Key to this success will be building a joint vision and a common reform roadmap among a broad range of central government agencies, state authorities, system operators and utilities.

India also faces the challenge of ensuring the financial health of its power sector which is dealing with surplus capacity, lower utilisation of coal and natural gas plants, and increasing shares of variable renewable energy. The government is working to improve the financial viability of the power sector. Faced with the challenge of some "stressed assets" in coal and gas-fired generation, it has been implementing a package of measures to enhance the economic efficiency of coal and gas supply for power generation and the availability of finance. The creation of a competitive wholesale power market will be vital for improving the utilisation of India's generation capacity.

India is making energy security a priority

India's electricity security has improved markedly through the creation of a single national power system and major investments in thermal and renewable capacity. India's power system is currently experiencing a major shift to higher shares of variable renewable energy, which is making system integration and flexibility priority issues. The Government of India has supported greater interconnections across the country and now requires the existing coal fleet to operate more flexibly. It is also promoting affordable battery storage.

International experience suggests that a diverse mix of flexibility investments is needed for the successful system integration of wind and solar PV. This flexibility is available not only from the coal fleet – it can also come from natural gas capacity, variable renewables themselves, energy storage, demand-side response and power grids. Many of these solutions are not yet fully utilised in India. To fully activate a diverse set of flexibility options, it is critical for the government to put in place electricity market reforms that enable the appropriate price signals and create a robust regulatory framework.

India's coal supply has increased rapidly since the early 2000s, and coal continues to be the largest domestic source of energy supply and electricity generation. Amid more stringent air pollution regulations, new coal power plants that are more efficient, flexible and relatively lower in emissions will be better positioned for their economic viability. By contrast, old and inefficient plants, which require expensive retrofits to comply with environmental standards, are in a difficult position. The government is identifying those plants that can and will need to run more flexibly in the system. It is also examining changes to market design to improve the remuneration of the system services they can provide. An efficient coal sector is critically important not only for electricity generation, but also for industrial development in areas such as steel, cement and fertilisers.

India is the world's third-largest consumer of oil, the fourth-largest oil refiner and a net exporter of refined products. The rate of growth of India's oil consumption is expected to surpass that of the People's Republic of China in the mid-2020s, making India a very attractive market for refinery investment. To maintain India's position as refining hub, the government is pursuing a very ambitious long-term roadmap to expand its refining capacity in line with the country's projected demand growth through 2040. As proven oil reserves are limited compared with domestic needs, India's import dependency (above 80% in 2018) is going to increase significantly in the coming decades.

To improve oil security, the government has prioritised reducing oil imports, increasing domestic upstream activities, diversifying its sources of supply and increasing Indian investments in overseas oil fields in the Middle East and Africa. Commendably, India is promoting domestic production with a major upstream reform, the Hydrocarbon Exploration and Licencing Policy (HELP), and is progressively building up dedicated emergency oil stocks. India's strategic petroleum reserve supplements the commercial storage available at refineries. India's current strategic reserve capacity of 40 million barrels can cover just over 10 days of current net imports. However, given the expected growth in oil consumption, the same volume may cover only four days of net imports in 2040. Therefore, it is important that the government pursue the second phase of its strategic stockholding policy, which would add an additional 50 million barrels, and also prepares subsequent phases. The IEA welcomes the government's efforts to intensify discussions with potential investors and supports India's collaboration with countries that have varied and comprehensive experience in stockholding and response capabilities.

The government aims to increase the share of natural gas in the country's energy mix to 15% by 2030, from 6% today. The IEA welcomes this ambition, which would allow India to improve the environmental sustainability and flexibility of its energy system. Increasing domestic gas production has been a key government priority, as output has unexpectedly come in below forecast levels over the past few years. India has five operating terminals for liquefied natural gas. Projects under construction could result in up to 11 additional terminals over the next seven years.

The role of gas has grown in India's residential and transport sectors but fallen in power generation, where imported natural gas remains squeezed by cheap renewables and coal. The government is committed to further liberalising the country's natural gas market. Strengthening regulatory supervision of upstream, midstream and downstream activities should be part of the market reforms, as it is likely to bring greater efficiency and drive up demand for gas and investment in gas transport infrastructure. A liquid and well-functioning domestic gas market would be a strong pillar for India's security of gas supply.

Significant progress in sustainable development

India has made important progress towards meeting the United Nations Sustainable Development Goals, notably Goal 7 on delivering energy access. Both the energy and emission intensities of India's gross domestic product (GDP) have decreased by more than 20% over the past decade. This represents commendable progress even as total energy-related carbon dioxide (CO_2) emissions continue to rise. India's per capita emissions today are 1.6 tonnes of CO_2, well below the global average of 4.4 tonnes, while its share of global total CO_2 emissions is some 6.4%.

India is an active player at international fora in the fight against climate change. The country's Nationally Determined Contribution under the Paris Agreement sets out targets to reduce the emissions intensity of its economy and increase the share of non-fossil fuels in its power generation capacity while also creating an additional carbon sink by increasing forest and tree cover. Although the emissions intensity of India's GDP has decreased in line with targeted levels, progress towards a low-carbon electricity supply remains challenging.

India has taken significant steps to improve energy efficiency, which have avoided an additional 15% of annual energy demand and 300 million tonnes of CO_2 emissions over the period 2000-18, according to IEA analysis. The major programmes target industry and business, relying on large-scale public procurement of efficient products such as LEDs and the use of tradable energy efficiency certificates. The government's LED programme has radically pushed down the price of the products in the global market and helped create local manufacturing jobs to meet the demand for energy-efficient lighting.

Based on current policies, India's energy demand could double by 2040, with electricity demand potentially tripling as a result of increased appliance ownership and cooling needs. Without significant improvements in energy efficiency, India will need to add massive amounts of power generation capacity to meet demand from the 1 billion air-conditioning units the country is expected to have by 2050. By raising the level of its energy efficiency ambition, India could save some USD 190 billion per year in energy imports by 2040 and avoid electricity generation of 875 terawatt hours per year, almost half of India's current annual power generation.

Recent IEA analysis shows that in 2018, India's investment in solar PV was greater than in all fossil fuel sources of electricity generation together. Large-scale auctions have contributed to swift renewable energy development at rapidly decreasing prices. By December 2019, India had deployed a total of 84 GW of grid-connected renewable electricity capacity. By comparison, India's total generating capacity reached 366 GW in 2019. India is making progress towards its target of 175 GW of renewables by 2022. In September 2019, the prime minister of India, Shri Narendra Modi, announced that India's electricity mix would eventually include 450 GW of renewable energy capacity. Progress towards these targets will require a focus on unlocking the flexibility needed for effective system integration. This can potentially be achieved by improving the design of renewables auctions, with clear trajectories and criteria to reflect quality, location and system value, along with measures to foster grid expansion and demand-side response across India.

India has been addressing energy-related environmental pollution since the 1980s, including air, water, land and waste issues. Reducing the health impacts of air pollution is a key priority. Over the years, the government has been progressively strengthened rules to combat air pollution, and adopted the National Clean Air Programme (NCAP), which focuses on monitoring and enforcement. Real progress on the ground has so far been limited, with the deadline for the enforcement of stringent air pollution standards for thermal power plants pushed back from 2017 to 2021/22. However, the implementation of the NCAP is expected to help improve this issue.

India is particularly vulnerable to climate change impacts and is exposed to growing water stress, storms, floods and other extreme weather events. Adaptation and resilience of the energy system to these extreme climate conditions should be a high political priority. Furthermore, the energy sector is a large water user. As India's energy demand continues to grow, the government should ensure that energy planning takes into account the water–energy nexus, as well as future space cooling needs.

Energy technology and innovation enables "Make in India"

Energy research, development and deployment (RD&D) can be a strong enabler of India's energy policy goals while also contributing to broader national priorities such as the "Make in India" manufacturing initiative. Through the initiative, the government is working to attract global companies to produce solar PV, lithium batteries, solar charging infrastructure and other advanced technologies in India. The government is strengthening its innovation efforts in a broad range of energy technology areas, including cooling, electric mobility, smart grids and advanced biofuels.

India's innovation-specific policy support have been important in driving energy technology development. As part of its climate policy agenda, the government has pursued a mission-based approach in many policy areas, including solar, water and energy. India has also been a leader in Mission Innovation and other multilateral collaborations, including the IEA Technology Collaboration Programmes. Recent years have shown a marked increase in clean energy RD&D funding, especially as India works to double its spending over five years under Mission Innovation. However, funding efforts are spread both thinly and widely across the government and its public sector companies.

India could benefit from integrating RD&D priorities with broader energy policy goals. Adopting an overarching energy RD&D strategy would provide a framework for co-ordinating the widespread activities of ministries that are engaged in directing, performing and funding energy RD&D. It would also support the engagement of private and public industry actors. Such an endeavour would benefit from the consistent collection and monitoring of energy RD&D data.

Towards more robust energy data and policy governance

Under the leadership of the prime minister, NITI Aayog fulfils an inter-ministerial co-ordinating role for national energy policy. A number of different ministries have responsibility for separate components of the energy sector. As energy policies become more intertwined, it is becoming increasingly desirable to strengthen co-ordination and develop a framework for the government's long-term energy agenda. This is particularly needed to create visibility for all stakeholders in the energy sector. The draft National Energy Policy by NITI Aayog, currently under consultation, is an excellent framework and should be adopted swiftly to guide policy making, implementation and enforcement across central and state governments.

Good quality and timely energy data are vital for monitoring, reviewing progress and enforcing the implementation of energy policies. The government has identified the critical importance of energy data and is taking action to improve their collection and dissemination. The IEA welcomes recent progress in the bilateral relationship between India and the IEA on energy statistics, which has led to the creation of cross-ministerial working groups co-ordinated by NITI Aayog.

Key recommendations

The Government of India should:

- Establish permanent energy policy co-ordination in the central government, with an overarching national energy policy framework to support the development of a secure, sustainable and affordable energy system.
- Continue to encourage investment in India's energy sector by:
  - ensuring full non-discriminatory access to energy transport networks
  - working with the states to implement power sector and tariff policy reforms with a focus on smooth integration of variable renewable energy and power system flexibility
  - moving from government allocation of energy supplies to allocation by market pricing
  - further rationalising subsidies and cross-subsidies.
- Prioritise actions to foster greater energy security by:
  - reinforcing oil emergency response measures with larger dedicated emergency stocks and improved procedures, including demand-restraint action and proper analysis of risks by using oil disruption scenarios and capitalising on international engagement
  - strengthening the resilience of India's energy infrastructure, based on a robust analysis of the water–energy nexus and cooling demand, notably when planning future investment.
- Improve the collection, consistency, transparency and availability of energy data across the energy system at central and state government levels.
- Adopt a co-ordinated cross-government strategy for energy RD&D, which enables impact-oriented measurement and dissemination of results.
- Ensure India's international energy collaboration continues to be strong and mutually beneficial, highlighting the country's energy successes and supporting continued opportunities to learn from international best practices.

2. General energy policy

Key data

(2017*)

TPES: 881.9 Mtoe (coal 44.3%, oil 25.3%, bioenergy and waste** 21.2%, natural gas 5.8%, hydro 1.4%, nuclear 1.1%, wind 0.4%, solar 0.4%), up 55% since 2007

TPES per capita: 0.66 toe (IEA average: 4.1 toe)

TPES per unit of GDP: 105 toe/USD million PPP (IEA average: 105 toe)

Energy production: 554.4 Mtoe (coal 48.7%. bioenergy and waste 33.8%, oil 7.4%, natural gas 4.8%, hydro 2.2%, nuclear 1.8%, wind 0.8%, solar 0.6%), up 31% since 2007

TFC: 591.2 Mtoe (oil 33.1%, bioenergy and waste 26.6%, coal 17.1%, electricity 16.9%, natural gas 6.1%, solar 0.1%), up 50.2% since 2007

Energy consumption (TFC) per capita: 0.44 toe (IEA average 2.9 toe)

*India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. So, the statement: "In 2017 total primary energy supply (TPES) was 881.9 Mtoe" refers to the data India has collected (and supplied to the IEA) from 1 April 2017 to 31 March 2018.

**Bioenergy and waste in this report mean solid and liquid biofuels, biogases, industrial waste and municipal waste. Bioenergy data are estimated by the IEA.

Note: Data are based on IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Country overview

With a population of 1.3 billion, India is the second most populous country in the world and the third-largest economy, measured by purchasing power parity (PPP). India has seen strong economic performance in recent decades, enabling a significant decrease in poverty levels, greater energy access for its citizens and growing penetration of cleaner energy across the economy. India has set a target growth rate of 9%, which would place it on a trajectory towards becoming a USD 5 trillion economy by 2024-25, making it the fastest-growing large economy in the world. India's sustained economic growth is placing an enormous demand on its energy resources, energy systems and infrastructure. Population density is high throughout most of the country, with the exceptions of the deserts in the west and the Himalayan mountains in the north. Around 45% of the land area is agricultural and over 24% is forest. Two-thirds of the population live in rural areas. However, the cities are growing fast and the urbanisation rate is around 2.4% per year.

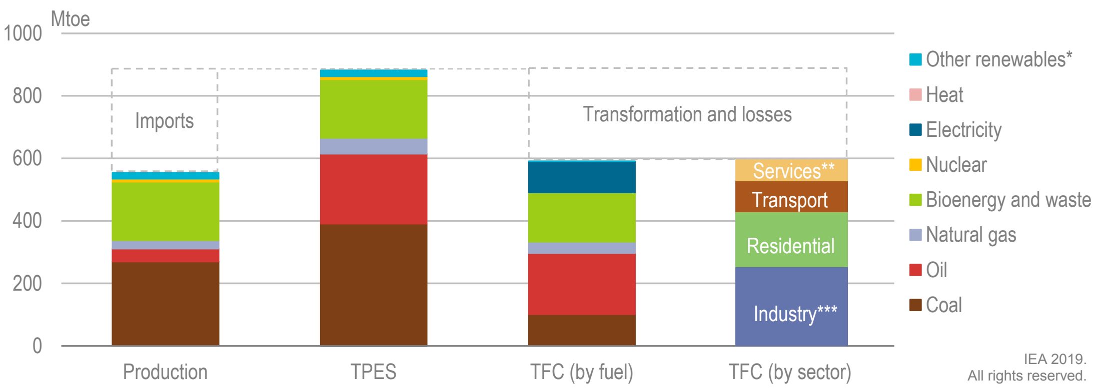
The largest cities are the national capital New Delhi (28.5 million), Mumbai (20.0 million), Kolkata (14.7 million), Bangalore (11.4 million), Chennai (10.5 million) and Hyderabad (9.5 million).

Major energy supply and demand trends

Over the past decades energy demand has steadily increased across all sectors, including agriculture, industry, commercial and residential, and is expected to continue to grow. Nonetheless, India's per capita energy consumption stands at 30% of the world's average (0.44 tonnes of oil equivalent [toe] per capita versus the global average of 1.29 toe and the International Energy Agency [IEA] average of 2.9).

India's energy system is largely based on the use of coal for power generation, oil for transport and industry, and biomass for residential heating and cooking (Figure 2.1). Bioenergy and most coal supply are produced in the country, while oil and natural gas are mainly imported. In 2017 India's total primary energy supply (TPES) was 882 million tonnes of oil equivalent (Mtoe), with nearly two-thirds being covered by domestic production (554 Mtoe). Industry accounted for the largest share of India's total final consumption (TFC), followed by the residential sector, transport and the service sector including agriculture.

Figure 2.1 Overview of India's energy system by fuel and sector, 2017



Domestic coal used in power generation and biofuels used in the residential sector form the main part of India's energy system, together with imported oil used in transport and industry.

**Other renewables* includes hydro, wind and solar.

***Services* includes commercial and public services, agriculture and forestry.

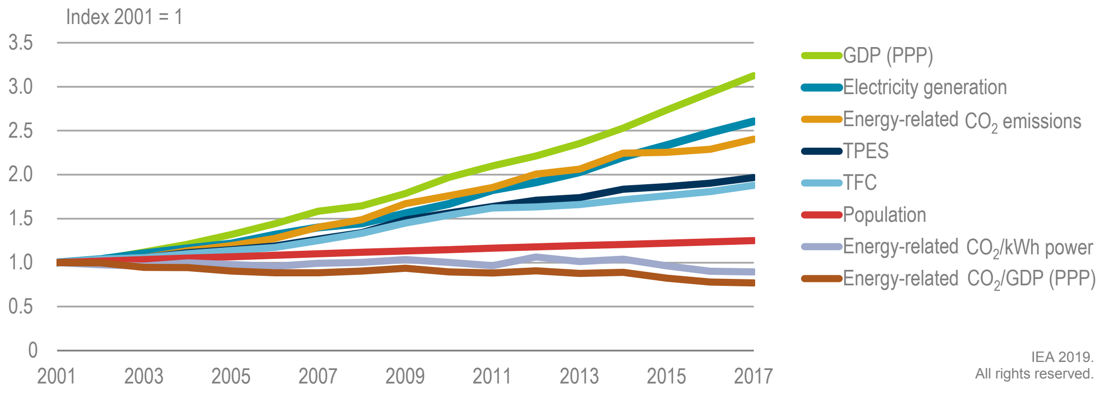
****Industry* includes non-energy consumption.

Notes: Bioenergy data are estimated by the IEA; the year runs from 1 April 2017 to 31 March 2018.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

India has been able to meet the gap between demand for and domestic supply of energy while addressing the environmental externalities associated with energy use. Despite high growth rates experienced in energy-intensive sectors, energy consumption and carbon dioxide (CO_2) emissions have not grown as rapidly as gross domestic product (GDP). Electricity supply is growing in line with economic growth, while its carbon intensity is in decline thanks to the increase in the share of renewables and declining utilisation of coal power plants (Figure 2.2). India has seen a reduction of around 13% in the emissions intensity of its economy (energy-related CO_2 emitted/GDP in PPP) during the past decade, while total final energy consumption and electricity generation continue to rise. The growth in CO_2 emissions has slowed and a minor decoupling of GDP growth from emissions has emerged since 2013.

Figure 2.2 Trends in the growth of the economy, population and energy indicators



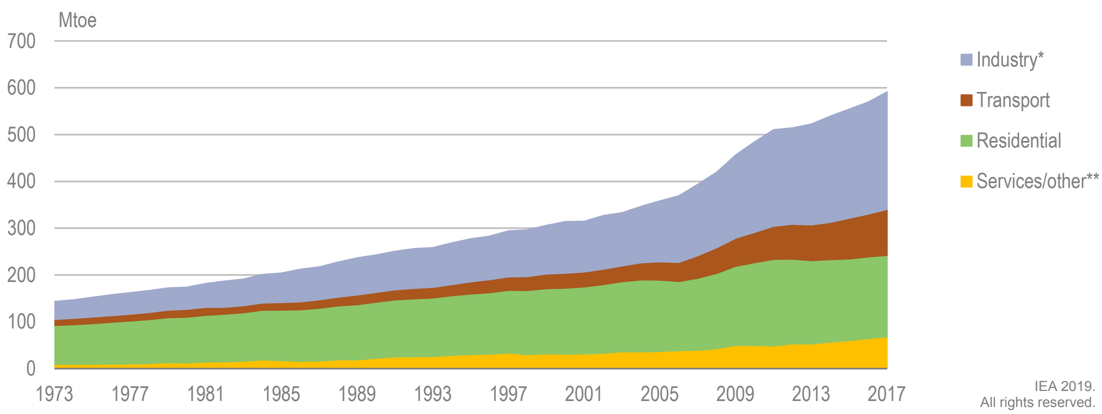
India's energy demand and emissions are steadily growing, driven by strong growth in GDP.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Energy consumption

India's TFC increased by 50% in the decade from 2007 to 2017, with significant growth across all sectors (Figure 2.3). Half of the growth came from the industrial sector, which accounted for 42% of TFC in 2017, including non-energy consumption.

Figure 2.3 TFC by sector, 1973-2017



India's TFC has increased by 50% in the past decade, with growth across all sectors, but the largest increases in industry and transport.

**Industry* includes non-energy consumption.

***Services/other* includes commercial and public services, agriculture and forestry.

Note: Years run from 1 April to 31 March.

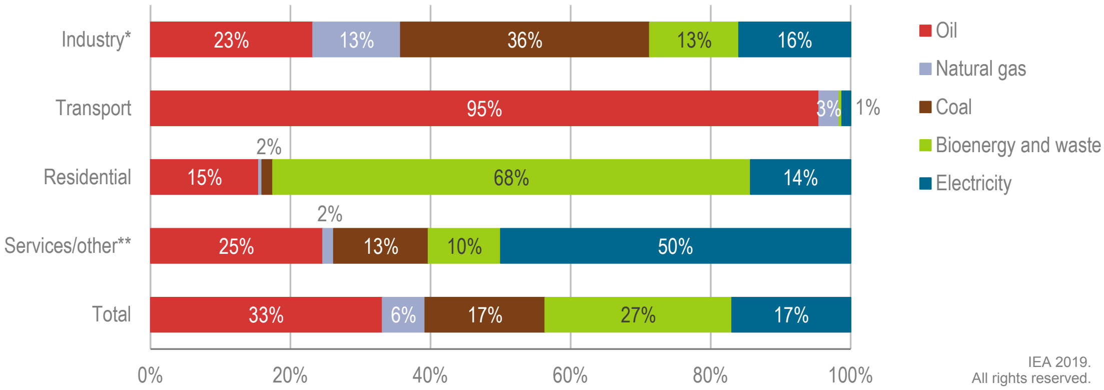
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Industry consumes a mix of coal, oil, natural gas, electricity and biofuels, with fossil fuels together representing 56% of total consumption (not counting electricity production) (Figure 2.4).

The residential sector is the second biggest energy consumer at 29% of TFC in 2017. Traditional use of biomass for heating and cooking accounts for the largest share of residential energy consumption, although the lack of sufficient data collection makes the numbers uncertain.

The transport sector is the third-largest energy consumer at 17% of TFC in 2017, dominated by oil fuels. Transport energy demand has more than doubled in a decade, accounting for one-quarter of TFC growth. Finally, the service sector including agriculture consumed 12% of TFC in 2017, with electricity accounting for more than half.

Figure 2.4 TFC by source and sector, 2017



India's sectors show large variations in energy source, with clear dominance of oil in transport, bioenergy in the residential sector and electricity in commercial consumption.

**Industry* includes non-energy consumption.

***Services/other* includes commercial and public services, agriculture and forestry.

Note: The year runs from 1 April 2017 to 31 March 2018.

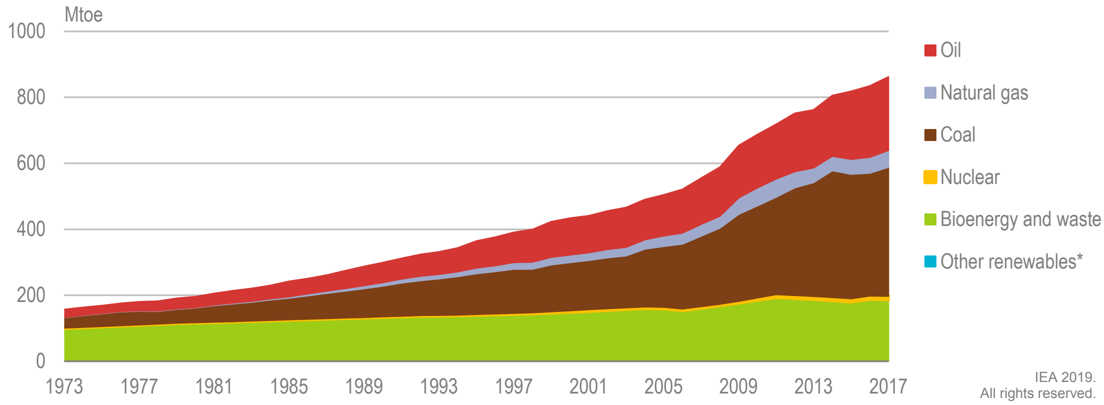
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Primary energy supply

The rapid growth in TFC, as well as in power generation to supply rising electricity demand, has led to a rapid increase in TPES. From 2007 to 2017 TPES increased by 55%, largely met by fossil fuels (Figure 2.5). Coal met 44% of TPES in 2017 and accounted for over half of the total growth in energy supply in the past decade. Oil is the second-largest primary energy source, providing 25% of TPES in 2017. Increased oil supply represented 26% of total growth in TPES in the last decade. Natural gas, by contrast, was not able to satisfy growing demand and its share of power generation and TPES has decreased in the past five years.

Bioenergy is the third-largest primary energy source in India, estimated to provide 21% of TPES in 2017. Compared to the rapid growth in fossil fuels, the increase in bioenergy supply has been modest. Hydropower supply has also been relatively stable, with around 10% growth in the past decade. Wind and solar, in contrast, have increased very rapidly, but from much lower levels. In 2017 together they accounted for just 1% of TPES. India also has a nuclear power fleet, which contributes around 1% to TPES.

Figure 2.5 TPES by source, 1973-2017



India's energy supply has increased by 55% in the last decade, relying on rapid growth in fossil fuels, which accounted for three-quarters of TPES in 2017.

**Other renewables* include hydro, solar and wind.

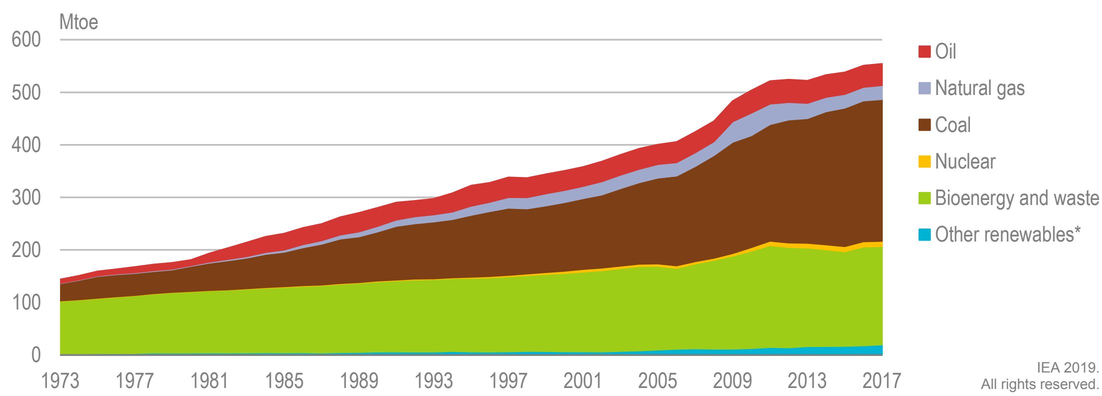
Notes: Bioenergy data are estimated by the IEA; years run from 1 April to 31 March.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Energy production and self-sufficiency

Coal and biomass dominate India's domestic energy production. In 2017 coal accounted for nearly half of total production, while bioenergy and waste were estimated to provide another third (Figure 2.6). India's oil and gas production is relatively low, and the country is dependent on imports, especially for oil (Figure 2.7).

Figure 2.6 Energy production by source, 1974-2017



Domestic energy production has steadily increased for several decades and is dominated by coal and bioenergy.

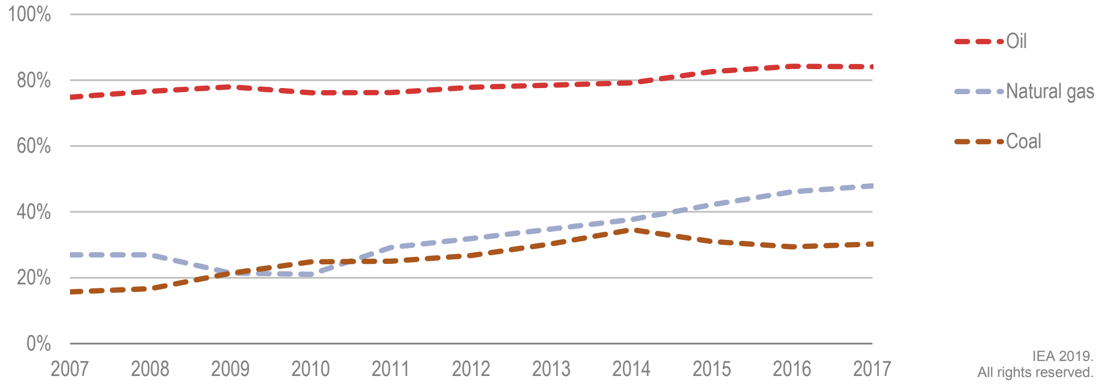
**Other renewables* include hydro, solar and wind.

Notes: Bioenergy data are estimated by the IEA; years run from 1 April to 30 March.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Despite rapid growth, domestic energy production has not kept up with the increase in energy demand. As a result, India has become increasingly dependent on imports. Imports of oil have been increasing at a constant rate and imports of natural gas are rising fast amid a sharp decline in domestic production (Figure 2.7). However, coal imports fell by about 12% between 2014 and 2016 because of weaker electricity demand and the government's focus on promoting domestic coal production to reduce coal imports.

Figure 2.7 Import dependencies for different energy sources in TPES, 2007-17

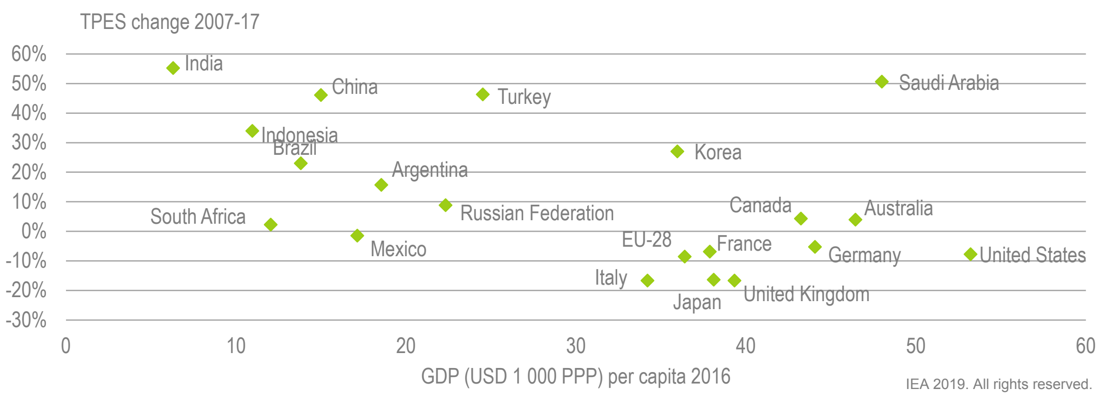


Domestic production has not kept up with increased energy demand, and India remains dependent on energy imports, especially of oil.

Notes: Energy net imports as share of TPES; years run from 1 April to 31 March.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Among the Group of Twenty (G20) countries, India's energy supply increased by 55% between 2007 and 2017, the highest growth rate, albeit from a low level (Figure 2.9) given that is has the lowest GDP per capita (Figure 2.8). With regard to the share of fossil fuels in India's energy mix (74%), the country ranks fifteenth lowest by comparison among the G20 (Figure 2.10).

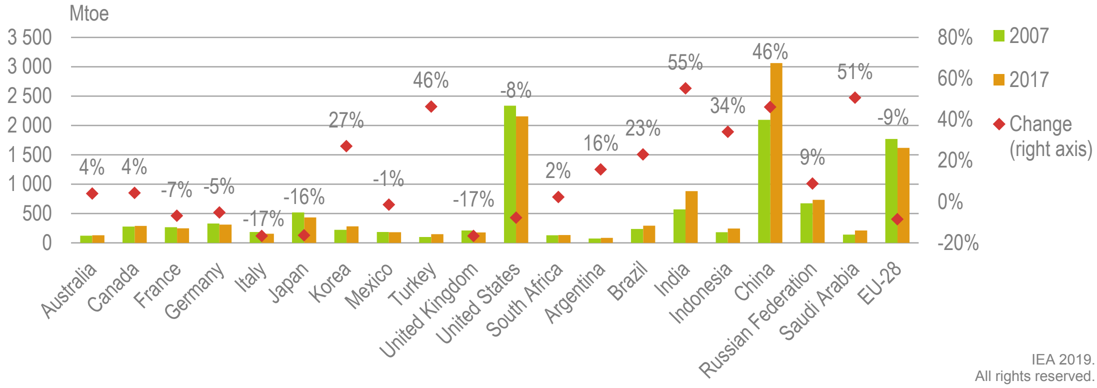
Figure 2.8 Change in TPES 2007-17 by GDP per capita 2016, G20 countries



India has seen the highest growth rate of TPES among the G20 countries, and has also the lowest GDP per capita.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

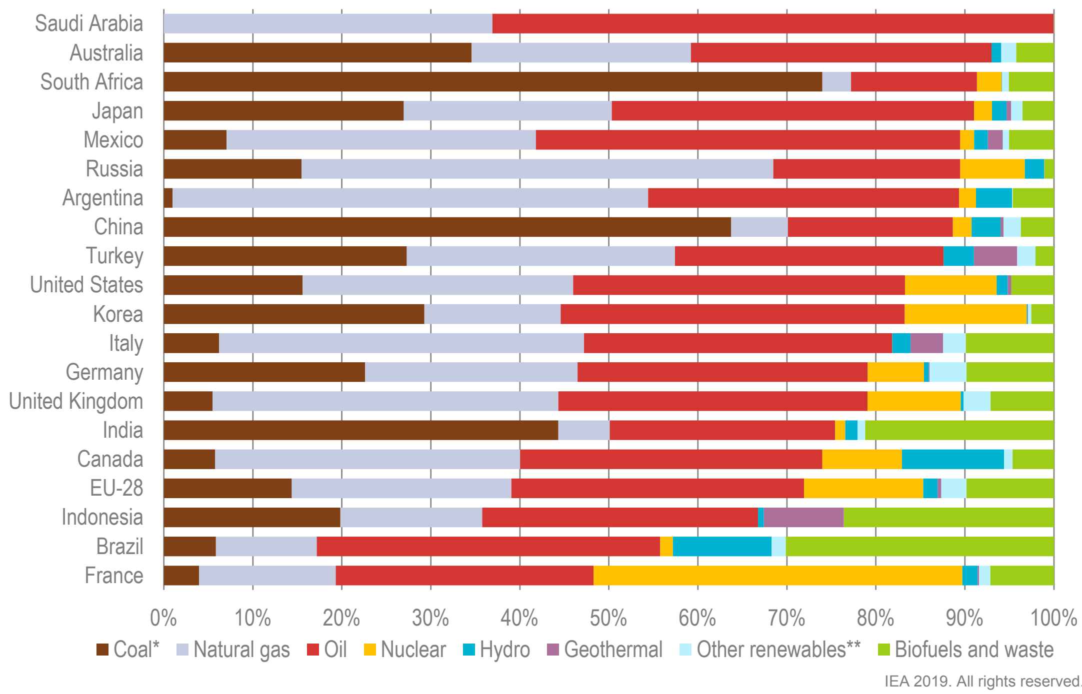
Figure 2.9 TPES by country, G20 countries, 2007 and 2017



India's energy supply increased by 55% between 2007 and 2017, but remains low compared to the major G20 economies United States and the People's Republic of China.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 2.10 TPES by fuel, G20 countries, 2017



India has a lower share of fossil fuels in TPES than most G20 countries, but that is mostly from traditional use of biomass.

**Coal* also includes shares of peat and oil shale.

***Other renewables* include hydro, solar and wind.

Notes: Does not include electricity imports and exports. Bioenergy data for India are estimated by the IEA. For India, the year run from 1 April 2017 to 31 March 2018.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Political system and energy sector governance

India is a federal parliamentary republic consisting of 28 states and 9 union territories, which results in a complex political decision-making environment with multi-level governance. Many economic policy objectives are linked to the year 2022, the year when the country will celebrate the 75th anniversary of its independence in 1947. The parliament (Sansad) has two houses: the Council of States (Rajya Sabha) and the House of the People (Lok Sabha). India held general elections for the House during April and May 2019.

The prime minister is elected by Lok Sabha members of the majority party, following legislative elections. The president is indirectly elected for a five-year term by an electoral college consisting of elected members of both houses of parliament. The head of state is President Ram Nath Kovind, in office since July 2017.

Prime Minister Modi presides over the large energy portfolio, which is spread across central (federal) and state governments, with the states having some autonomy over energy policy. At federal level, India does not have one single ministry in charge of energy policy. The Government of India (GoI) has at least five ministries with responsibilities for energy: the Ministry of Power (MoP), the Ministry of Petroleum and Natural Gas (MoPNG), the Ministry of New and Renewable Energy (MNRE), the Ministry of Coal (MoC) and the Department of Atomic Energy (DAE) (Figure 2.11).

Electricity sector

The MoP governs the electricity sector in India and also hosts the Bureau of Energy Efficiency (BEE). The Central Electricity Authority (CEA) is the main advisor to the MoP and is responsible for the technical co-ordination and supervision of programmes and data collection and dissemination, notably through the five-year National Electricity Plan. Under the Electricity Act 2003 the Central Energy Regulatory Commission (CERC) is responsible for: fixing tariffs (regulated tariff and the tariff discovered through competitive bidding); licensing of transmission and trading; market development (facilitating open access, licensed traders, power exchanges); grid security (grid code, deviation settlement mechanism, ancillary services); regulating the interstate transmission system; adjudication of disputes; promotion of renewable energy sources; consumer protection; among other matters. The State Electricity Regulatory Commissions (SERCs) collaborate through the Forum of Regulators (FoR).

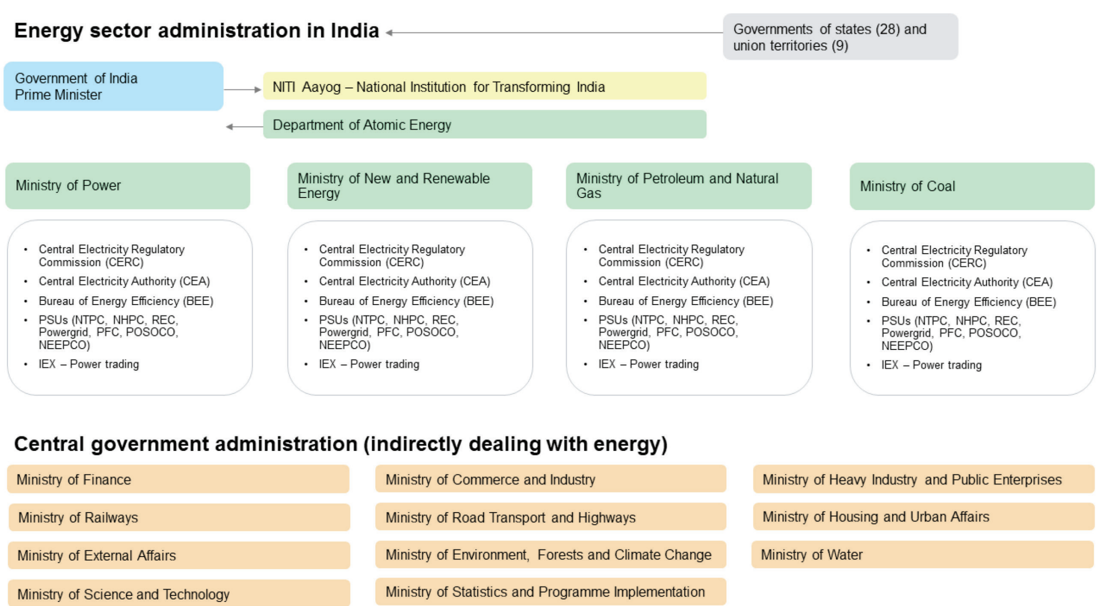
Public-sector undertakings (PSUs) under the MoP include the Power Finance Corporation (PFC) and Rural Electrification Corporation, which function as non-banking financial institutions and provide loans for power sector development. National Thermal Power Corporation (NTPC) is India's largest integrated thermal power company and the National Hydroelectric Power Corporation (NHPC) the largest hydropower producer. In addition, the MoP oversees the functioning of the North Eastern Electric Power Corporation (NEEPCO), the system operator Power System Operation Corporation (POSOCO) and the central transmission utility Power Grid Corporation of India Limited (Powergrid).

India has several electricity transmission operators in the country. Powergrid owns and operates the majority of the interstate transmission lines, while intrastate lines are owned by the state transmission utilities. As recent reforms opened the sector to private or merchant investment, private-sector entities also build, own and operate interstate transmission lines.

Some energy-related departments are run directly under the Prime Minister's Office. These include the DAE, which works on the development of nuclear power technology and the application of other radiation technologies, and NITI Aayog, which is an official think tank and policy advisory body of the GoI, co-ordinating activities that are inter-ministerial in nature, such as India's electric vehicle (EV) programme and reform of energy data. The DAE has a mission to enhance the share of nuclear power in the power sector by deployment of indigenous and other proven technologies, as well as thorium-based reactors with associated fuel cycle facilities. A central-government-owned corporation administered by the DAE, the Nuclear Power Corporation of India Limited (NPCIL) is responsible for the generation of nuclear power, operating India's 21 nuclear reactors.

The MNRE is in charge of the development of solar, wind and other renewables in India. Under the MNRE are the National Institute of Solar Energy, the National Institute of Wind Energy and the Indian Renewable Energy Development Agency (IREDA), which functions as a non-banking financial institution providing loans for renewable energy and energy efficiency projects. Solar Energy Corporation of India (SECI) is responsible for the implementation of various MNRE subsidy schemes, such as the solar park scheme and the grid-connected solar rooftop scheme. Biofuels are managed by the MoPNG.

Figure 2.11 Main institutions involved in energy policy making in India



Coal sector

The MoC has oversight of exploration, exploitation and the development of coal and lignite resources in India. Under the ministry, the Coal Controller Organisation is responsible for the sampling of coal, inspection of collieries, issuing guidelines for the maintenance of grades of coal, granting permission for the opening and closure of mines, and collecting and disseminating coal statistics. It is also the appellate authority in case of dispute. India's largest coal mining company, Coal India Limited (CIL), is under the authority of the MoC.

Oil and natural gas sectors

The MoPNG is in charge of policies relating to the petroleum and natural gas sectors. The ministry co-ordinates the upstream regulator, the Directorate General of Hydrocarbons (DGH), and downstream regulator, the Petroleum and Natural Gas Regulatory Board (PNGRB). The ministry also co-ordinates hydrocarbon data collection (Petroleum Planning and Analysis Cell) and investment through the Oil Industry Development Board. Most of the oil and gas companies in the country are PSUs, which are organised through the MoPNG. These include the county's largest oil and gas producer Oil and Natural Gas Corporation (ONGC), the largest refiner and retailer Indian Oil Corporation Limited (IOCL), and India's largest state-owned natural gas company GAIL, with activities in production, transmission, distribution and sales.

Climate and environment

The Ministry of Environment, Forests and Climate Change (MoEFCC) is in charge of environmental and forestry management and climate action planning. The MoEFCC operates centres of excellence to increase public awareness of the environment, for example the Centre for Environment Education, Centre for Ecological Sciences and Centre for Mining Environment. The Prime Minister's Council on Climate Change brings together all ministers and non-governmental members (think tanks, non-governmental organisations) to drive the implementation of India's climate policies.

Other ministries

The Ministry of Commerce and Industry and its Department of Promotion of Industry and Internal Trade are in charge of the "Make in India" programme to develop domestic manufacturing, including in the energy sector. The Department of Commerce under this ministry formulates, implements and monitors India's foreign trade policy. A Ministry of Water was created in 2019.

Other ministries that indirectly or partly deal with energy issues are: the Ministry of Finance with oversight of subsidy programmes and the financial health and restructuring of the energy sector; the Ministry of Railways, which manages India's rail network and operations; the Ministry of Science and Technology (MoST), which organises and co-ordinates science and technology activities; and the Ministry of Statistics and Programme Implementation (MoSPI), which is in charge of collecting and disseminating a broad range of statistics. In addition, the Department of Chemicals and Petrochemicals under the Ministry of Chemicals and Fertilisers is responsible for policy making, planning, development and regulation of chemicals and petrochemical industries in India.

Governance of public companies in the energy sector

India's largest companies in which the GoI holds more than 50% are referred to as PSUs. Central government owns PSUs across the energy sector, notably in mining and exploration (crude oil, coal and natural gas), petroleum refining and marketing, power generation, nuclear energy and power transmission.

The top ten profit-making companies in India are energy sector PSUs, according to the latest survey of PSUs in 2017-18 (see Table 2.1). In coal mining, CIL was responsible for 82% of the country's coal production in 2017. In refining, IOCL is the largest operator, owning nine refineries with 28% of India's total refining capacity. (Reliance, a private company, is the second-largest player in refining and India's largest oil product exporter.) ONGC is India's largest oil and gas exploration and production company. It produces 62% of India's crude oil and condensate and 72% of its natural gas. In the power sector, around 45% of generation is privately owned, a sharp increase since 2008 when only 8% was private. (This does not include private generation of electricity for auto-consumption, owned by industry players, often referred to as captive power generators.) The majority of generation (55%) is owned by government (30% by the states and 25% by the central government). Owned by the central government, the NPCIL is responsible for the generation of nuclear power and operates 21 nuclear reactors. With a government shareholding of 57.9%, Powergrid owns and operates the interstate transmission lines. In 2017 the GoI held 58.32% of the Rural Electrification Corporation, a share which has been reduced from 81.82% in 2008 (through public offerings) to leverage funding for the country's electrification.

The net profit margins of energy PSUs are the highest in the mining and exploration sector, followed by generation, while transmission has a net profit margin of below 4% (DPE, 2018). In the power sector, the DPE benchmarked PSUs against the private sector (Adani Power, Tata Power). NTPC achieved a net profit margin of 12% and NPCIL 29% (Table 2.2), while private generators reported negative net profit margins in 2017/18.

Table 2.1 Top-performing profit-making PSUs in India

Rank	Company	Net profit (INR crore)	Net profit (USD billion)	Share of all PSU profits (%)
1	IOCL	21 346	3.01	13.37
2	ONGC	19 945	2.81	12.49
3	NTPC	10 343	1.46	6.48
4	CIL	9 293	1.31	5.82
5	Powergrid	8 239	1.16	5.16
6	Bharat Petroleum Corporation	7 919	1.11	4.96
7	Hindustan Petroleum Corporation	6 357	0.89	3.98
8	Power Finance Corporation	5 855	0.82	3.67
9	Mahanadi Coalfields	4 761	0.67	2.98
10	Rural Electrification Corporation	4 647	0.65	2.91
	Other PSUs	60 934	8.58	38.17

Note: A crore is 10 million.

Source: DPE (2018), *Public Enterprises Survey 2017-18*, https://dpe.gov.in/public-enterprises-survey-2017-18.

Table 2.2 Key financial indicators of PSUs vs private companies in the power sector, 2017-18

Names of the companies	Net profit margin (%)	Return on assets (%)	Long-term debt/equity ratio
Public sector			
NTPC	12.14	3.98	1.07
NPCIL	28.86	4.93	0.92
NHPC	5.16	32.74	0.59
Private sector			
Adani Power	-0.28	-0.12	0.24
Tata Power	-37.21	-8.63	0.56

Source: DPE (2018), *Public Enterprises Survey 2017-18*, https://dpe.gov.in/public-enterprises-survey-2017-18.

At the time of writing, there are 8 Maharatnas[1] and 16 Navratnas in India. The Maharatnas included Bharat Heavy Electricals Limited (BHEL), Bharat Petroleum Corporation Limited CIL, GAIL, IOCL, NTPC, ONGC, Powergrid and Steel Authority of India Limited. Among the Navratna are Power Finance Corporation Limited and Rural Electrification Corporation Limited.

The governance of each PSU depends on the ministry (the "line ministry") that exercises ownership rights and is responsible for the vision, mission and long- and short-term objectives of the PSU. In most cases the board of the PSU has limited autonomy to decide on the company's management structure, such as the appointment and removal of the CEO, and, to a lesser extent, strategy formulation. The Department of Public Enterprises (DPE), as part of the Ministry of Heavy Industries, acts as the "nodal" agency for all PSUs and sets the policies guiding performance improvement and evaluation, financial accounting, personnel management and related areas.

Over the past decade the GoI has continuously reformed the governance of the PSUs with the objective of increasing their autonomy and management efficiency, while strengthening the transparency, accountability and auditing of operations. The DPE adopts regulations, in conjunction with sectorial regulatory bodies, and deals with the corporate governance of the sector through governance guidelines (in line with OECD Guidelines 2007). PSUs are required to submit quarterly compliance or grading reports to their line ministries. Memorandums of understanding have been signed by most PSUs and have emerged as a key tool for monitoring and motivating performance and controlling debt levels. While the top 10 PSUs are performing well, the DPE reminds in its 2017/18 PSU survey of the "sickness" of many PSUs, which still "include old and obsolete plant and machinery, outdated technology, low capacity utilisation, low productivity, poor debt–equity structure, excess manpower, weak marketing strategies, stiff competition, lack of business plans, dependence on Govt. orders, heavy interest burden, high input cost, resource crunch, etc." (DPE, 2018).

No major privatisation has taken place in the past decade, but the GoI has reduced shareholdings by disinvestment through public listing and selling stakes of listed companies while maintaining majority ownership.

Economy and the energy sector

India's economy is growing rapidly, with real annual growth rates of around 7% in recent years. It has experienced an average of 7.4% growth over the last 15 years; in 2017/18 it was 6.8% and in 2018/19 it was 7.2%, according to the Ministry of Finance.

India has a diverse economy that includes traditional village farming, modern agriculture, handicrafts, a wide range of modern industries, and a multitude of services. Slightly less than half of the workforce is in agriculture, but services are the major source of economic growth, accounting for nearly two-thirds of India's output but employing less than one-third of its labour force. India has capitalised on its large educated English-speaking

[1] Maharatna status allows state companies greater financial autonomy. The status is granted to companies that had Navratna status and are listed on Indian stock exchange with minimum prescribed public shareholding under SEBI regulations with an average annual turnover of more than INR 25 000 crore, during the last 3 years; an average annual net worth of more than INR 15 000 crore, during the last 3 years; an average annual net profit after tax of more than INR 5 000 crore, during the last 3 years; and significant global presence and international operations.

population to become a major exporter of information technology services, business outsourcing services and software workers.

India's GDP in PPP is the third largest among the G20 largest economies, after the People's Republic of China ("China") and the United States. In terms of per capita income, however, India remains below the world average and ranks last among the G20. In 2017 India's GDP per capita (in PPP) was USD 7 200 (2017 prices and PPP), significantly below the IEA average of USD 39 250 (2010 prices and PPP). In recent years the country has made a significant dent in poverty levels, with extreme poverty dropping from 46% in 1995 to an estimated 13% in 2015. India's ability to achieve rapid sustainable development will have profound implications for the world. The world will only be able to eliminate poverty if India succeeds in lifting its citizens above the poverty line.

Over the past ten years the GoI has spent over USD 1 trillion on infrastructure according to the Ministry of Finance, as it promoted investment in manufacturing and development through fiscal incentives and policies in transport, power and urban and rural infrastructure. Reforms and liberalisation were enacted to boost foreign direct investment and remove bottlenecks in the supply of key raw materials. Major economic growth initiatives include Skill India, Digital India and Make in India. The Start-up India initiative aims to encourage entrepreneurship and job creation, boosting the agricultural sector with a focus on micro-irrigation, watershed development, soil conservation and credit, and various measures to improve clarity and transparency in economic policy-making.

The 2019 budget set out a ten-point vision for economic growth in the next decade, with a financial package to support investment in physical and social infrastructure and promote the Digital India initiative, a pollution-free India, and the Make in India initiative for micro, small and medium-sized companies and start-ups in the automotive, electronics, batteries, and water and water management sectors. To attract foreign direct investment, the government plans competitive tenders for mega-scale manufacturing facilities for EVs, charging stations, solar photovoltaic (PV) cells and lithium ion batteries, and proposes financial incentives for EVs. In the 2019 budget the GoI put a major focus on further improving the financial health of the power sector by strengthening the conditions of public loans to power distribution companies (DISCOMs) and adopting a new tariff policy. Moreover, the GoI announced reform of the gas and oil markets.

Although economic performance has been strong, development has been uneven, with the gains of economic progress spread unevenly between population groups and geographic areas. Furthermore, India has a very large infrastructure deficit – it is estimated that India would need to spend USD 200 billion (7-8% of GDP) on infrastructure annually and USD 5 trillion in total till 2030 at current exchange rates to eliminate it. The GoI spends around 4-5% of GDP on infrastructure investment annually, but its financing is restricted under the financial discipline and limits imposed under the Fiscal Responsibility and Budget Management Act of 2003. New insolvency and bankruptcy-related legislation aims to improve the financial health of the enterprises, including those in the energy sector. Private investment is made on a project finance basis. In many sectors, 50-70% of the debt comes from the banking sector, while institutional investors are only involved to a small extent.

Financial health of the power sector

One particular area of concern has been the power sector. India's electricity generators suffer from financial stress due to the rapid addition of capacity amid slower than expected electricity demand growth. This left many generators with underutilised capacity and new projects without adequate power purchase agreements (PPAs) or without fuel supply agreements (FSAs), causing delays for project promoters. The failure of DISCOMs to pay generators, or their delay in paying, has left project owners unable to service their debt or get fresh equity or working capital (HLEC, 2018).

The 67 DISCOMs, mostly owned by the states, have faced chronic physical commercial and technical losses due to the lack of metering and low payment collection rates, leading to high levels of debt and delayed payment or non-payment to generators. The GoI Department of Financial Services identified 34 coal-fired projects with a total capacity of 40.1 gigawatts (GW) as so-called stressed assets, broken down into 24.4 GW of commissioned capacity and 15.7 GW of projects under construction, mostly belonging to independent power producers (IPPs). Besides this coal-fired capacity, there are also 14 GW of non-performing gas-fired power plants, following the halt of domestic gas production.

In February 2018 the Reserve Bank of India (RBI) adopted the circular on a revised framework for stressed assets, according to which a company could be declared bankrupt even if it missed its repayment schedule by one day. Once a company was in default, for loans above INR 2 000 crore (USD 0.28 billion) the lenders would have to implement a resolution within 180 days, or otherwise file a bankruptcy application with the court within 15 days of the expiry of the 180 days. This circular prohibited loan restructuring and caused much stress to companies in the energy infrastructure and power sectors.

On 2 April 2019 the Supreme Court annulled the RBI circular on the grounds that it was beyond the powers of the RBI. The Supreme Court mandated RBI to exercise its powers under Section 35AA "in respect of specific defaults by specific debtors". The Supreme Court's judgment came as a relief to the stressed assets in the power sector as the ruling restored banks' discretion to invoke insolvency proceedings under the Insolvency and Bankruptcy Code on case-by-case basis. In June 2019 the RBI adopted the new "prudential framework for resolution of stressed assets". By doing away with mandatory referral of stressed accounts under the code, the new framework puts the onus on banks to devise a suitable resolution plan. Lenders can review a borrower's account within 30 days following a default. However, it stipulates additional provisions in case of delayed implementation of the resolution plan.

While the defunct circular was applicable only to scheduled commercial banks (excluding regional rural banks) and all-India financial institutions, the new circular is also applicable to small banks and systemically important non-deposit-taking non-banking financial companies and deposit-taking non-banking financial companies. All lenders must put in place board-approved policies for resolution of stressed assets. Lenders also have to report to the GoI credit information on all borrowers to whom they have aggregate exposure of INR 5 crore and above.

Since 2015 the GoI has adopted a range of measures to address concerns surrounding stressed assets, which are explained in detail in the respective sector chapters and provided here as an overview. The GoI's High-Level Empowered Committee issued a number of recommendations in 2018 to improve coal supply, allow for the pass-through of additional cost in electricity tariffs and improve DISCOM revenues by introducing late-payment surcharges, payment security mechanisms and other measures.

- The GoI introduced a new gas auction mechanism for electricity generating units by pooling any domestically produced gas with imported liquefied natural gas (LNG) and covering the increased cost under the Power System Development Fund.

- In 2017 the MoC started auctioning coal supply contracts (so-called linkages) for IPPs with PPAs under the Scheme for Harnessing and Allocating Koyala (coal) Transparently in India (SHAKTI), rationalised coal prices (coal escalation index) and introduced third-party sampling of coal to improve coal quality and efficiency of plants and reduce generation costs.
- The GoI also introduced flexibility in existing coal FSAs (coal that had been assigned to generators, the so-called linkage coal), allowing the coal to be used for short-term PPAs and that power to be sold through the Discovery of Efficient Energy Price (DEEP) bidding portal.
- A competitive procurement scheme was introduced to allocate three-year power purchase contracts for 2 500 megawatts (MW) of generation that had no PPA.
- The MoP directed the CERC to allow the pass-through of additional costs due to the installation or upgrade of emissions control systems as well as of any change in domestic duties, levies, cess and taxes under the Tariff Policy of 2016.
- Under the UDAY (Ujwal DISCOM Assurance Yojana) scheme, states agreed to convert 75% of DISCOM debt into state government bonds. The accumulated financial liability of the state-owned DISCOMs (INR 4.3 trillion or USD 60 billion) was transferred to their owners, the state governments, in return for improving the efficiency of the DISCOMs, cutting losses and achieving greater financial discipline. An online portal (the PRAAPTI app) was created to foster payment transparency and invoicing discipline among DISCOMs.

Energy and climate policy

With regard to energy, the GoI set out high-level national targets for the year 2022, the anniversary of India's independence. The GoI aims to achieve 100 smart cities, LPG connections to all housing, universal electricity access and 175 GW of renewable electricity capacity. India's 2008 National Action Plan on Climate Change (NAPCC) set out eight national missions to promote India's sustainable development objectives, which are as follows:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change.

India's energy efficiency flagship programmes are part of the National Mission on Enhanced Energy Efficiency and focus on industry and business sectors: the Perform Achieve and Trade (PAT); the Energy Efficiency Financing Platform (EEFP); Framework for Energy Efficient Economic Development (FEEED); and the Market Transformation for Energy Efficiency (MTEE). The PAT is a domestic cap-and-trade mechanism that supports energy efficiency in energy-intensive segments, such as the industrial and power sectors. Plants are assigned an energy consumption target. If a plant beats its target over the three-year compliance period, it can issue Energy Saving Certificates (ESCerts) that can be traded (since 2017). Plants that miss their targets can purchase ESCerts or face a penalty. The first cycle of the PAT scheme (2012-15) targeted 478 plants across eight sectors,[2] achieving 8.67 Mtoe in energy savings, corresponding to reducing 31 million tonnes of CO_2 equivalent (Mt CO_2-eq).[3] The PAT cycles II, III and IV are being implemented with 848 designated consumers (plants).

The EEFP provides a platform to facilitate the interaction between financial institutions and project developers to invest in energy efficiency projects. It is supported by the FEEED, which has two financial instruments to leverage financing for energy efficiency through risk mitigation: the Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE); and the Venture Capital Fund for Energy Efficiency (VCFEE).

MTEE is India's principal initiative aimed at accelerating the adoption of energy-efficient appliances through the Bachat Lamp Yojana – the roll-out of energy-efficiency compact fluorescent lamps (CFLs) at the same price as incandescent bulbs. To date, 29 million CFLs have been distributed, saving 415 megawatt hours (MWh) of consumed energy, and the Super-Efficient Equipment Programme (SEEP), designed to bring accelerated market transformation for super-efficient appliances.

At the Conference of the Parties (COP) 15 in Copenhagen in 2008, India announced voluntary targets to reduce the emissions intensity of its GDP by 20-25% against 2005 levels by 2020. In 2015 the GoI built on this target in its submitted Intended Nationally Determined Contribution (INDC), conditional upon financial assistance, which became India's first Nationally Determined Contribution (NDC) after the GoI ratified the Paris Agreement in 2016. India's NDC focuses strongly on action in the energy sector and includes the following energy sector-related targets:

- To reduce the emissions intensity of GDP by 33-35% from 2005 levels by 2030.
- To achieve about 40% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, conditional on the transfer of technology and low-cost international finance including from the Green Climate Fund (GCF).
- To create an additional carbon sink of 2.5-3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.
- To better adapt to climate change by enhancing investment in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.

At the United Nations' Climate Summit in September 2019, Prime Minister Modi announced an increased ambition to promote renewable energy towards a target of 450 GW (without indicating a time frame).

Under overall energy sector planning, India's policy objectives for sustainable development are set out in the 2030 Vision, the Seven-Year Strategy and a Three-Year Action Agenda, all prepared by NITI Aayog in line with the United Nations' Sustainable Development Goals. The 2030 Vision states that "By 2031-32, we must transform India into a prosperous, highly educated, healthy, secure, corruption-free, energy-abundant, environmentally clean and globally influential nation".

[2] Aluminium, cement, chlor-alkali, fertilisers, iron and steel, pulp and paper, textiles and thermal power plants.
[3] https://beeindia.gov.in/sites/default/files/Booklet_Achievements%20under%20PAT_May%202017.pdf.

Energy taxation and subsidies

The GoI provides large-scale public subsidies to ensure access to electricity, energy and clean cooking for its population. Subsidies are designed for the purpose of social support and economic development, but they are a large financial burden on the GoI budget, notably at times of rising prices for energy commodity imports. The GoI has gradually phased out and rationalised oil product subsidies and streamlined energy taxation. Many subsidies have been reduced and better targeted at vulnerable consumers. Renewable subsidies have been on the rise, while coal subsidies are stable or in decline.

Goods and Services Tax

In 2017 the central GoI introduced the Goods and Services Tax (GST), with the aim of further rationalising taxation and reducing overlapping taxes between state and central governments. Not all energy sectors are covered and not at the same rate. Petroleum products (crude oil, gasoline, diesel and kerosene), natural gas and electricity do not fall under the GST as they incur central excise duty and state value-added tax (VAT). Other fuels such as coal, naphtha, furnace oil, and liquefied petroleum gas (LPG) have been brought under the GST. Both imported and domestic coal are subject to the coal compensation cess (levy) of INR 400 (USD 5.70) per tonne. Prior to the introduction of the GST, the GoI raised a separate Clean Energy Tax (coal cess), with the revenues going to the National Clean Energy Fund. This tax revenue is now redirected to compensate for taxation imbalances caused by the GST reform for states (compensation cess). Renewable energy devices and parts for their manufacturing are supported by a lower GST rate of 5%, while inputs to thermal generation are charged GST of 5% to 18%. At the end of 2019, the GoI proposed to waive the coal compensation cess.

Subsidies

In 2018 India spent a total of USD 25 billion on subsidies for the consumption of fossil fuels, according to the latest IEA data (IEA, 2019b), mostly supporting oil consumption in the form of LPG (USD 17 billion) and gas consumption (USD 4 billion). However, the total value of fossil fuel subsidies is only 1% of GDP.

The diesel subsidy ended in 2014/15. Kerosene and cooking gas (LPG) are the only oil products subsidised by the government in 2019, but the GoI is increasing their price gradually to phase out the subsidies. According to the GoI, the oil subsidy accounted for USD 3.5 billion in 2018/19, a continuous decrease from the level of subsidy of USD 14 billion in 2012/13 and 11 billion in 2014/15.

The government subsidy programmes for access to electricity and clean cooking, which are outlined below, have contributed to a major reduction in kerosene use and related subsidies.

The IISD-CEEW energy subsidies inventory shows a 70% decline in the total amount of India's fossil-fuel subsidies, driven not only by the decline in global oil prices, but also major reforms of gasoline, diesel, cooking gas and kerosene consumption subsidies (IISD and CEEW, 2018). IISD-CEEW found coal subsidies (support to both mining and power generation), mostly through tax breaks that reduce the cost of coal to power plants, but saw an overall decline with the introduction of the GST. Renewable energy and coal mining and consumption were subsidised in 2017 at a total amount of USD 2.2 billion and USD 2.4 billion, respectively.

Electricity access

The GoI has been supporting the expansion of distribution grid infrastructure across India to foster electricity access in villages. It provides budgetary support (grants) to state government DISCOMs under the Deendayal Upadhyaya Gram Jyoti Yojana (in rural areas), the Saubhagya scheme (last-mile connectivity to households) and the Integrated Power Development Scheme (IPDS) (in urban areas). The co-ordinated cross-government schemes focus on strengthening distribution networks and increasing village and household connections by co-funding network upgrades and extensions by the DISCOMs. The GoI announced that India had achieved its goal of providing electricity to every village in India in April 2018, an impressive achievement, delivered ahead of schedule. A village is considered to be electrified when 10% of households and all public buildings are connected to the grid. The final 600 000 villages (and a further 26 million households) had gained access to electricity, according to the latest government data in April 2019.[4] IISD-CEEW expects consumption subsidies to increase as a greater share of the population now have access to electricity, but not the financial capacity.

Under the National Electricity Policy, electricity is subsidised for the agricultural sector and domestic consumers below the poverty line (BPL). This subsidy is partly recovered through higher tariffs paid by the industrial and commercial sectors and direct subsidies from state governments to the DISCOMs. Electricity tariffs are below the cost of electricity, which impacts the financial health of many DISCOMs. Central government has entered into joint initiatives with individual states to ensure the DISCOMs' financial viability for delivering universal electricity access.

Under the UDAY scheme, since 2015 state governments (which own the DISCOMs) have been allowed to take over 75% of their DISCOM's debt and pay back lenders by selling bonds. DISCOMs are to repay the remaining 25% through the issuance of bonds, in exchange for improvements in operational targets. By March 2017, 27 states had entered into memorandums of understanding with the government for the UDAY scheme.

Several support programmes for universal electricity access have included reforms to reduce and better target the subsidy. The Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) programme, with a total budget of USD 10.8 billion, also required the separation of household and agricultural feeders to avoid the overcompensation of agriculture. The Saubhagya scheme allocated a total budget of USD 1.8 billion to support the provision of electricity to individual households.

One of the major reform efforts is the GoI work with states towards tariffs progressively reflecting the cost of supply of electricity, based on roadmaps for the reduction of cross-subsidies, established by the SERCs. Tariffs for all consumer categories are to be brought within ± 20% of the average cost of supply and cross-subsidies reduced. Subsidy to any category of consumers has to be provided through Direct Benefit Transfer[5].

Clean cooking

To promote clean cooking, the GoI subsidises the provision of LPG (also known as cooking gas) in order to reduce the exposure to indoor air pollution from burning wood or dung and

[4] India's central online tracking of electricity access can be found at: http://garv.gov.in/dashboard.

[5] The GoI introduced the direct benefit transfer in 2013 to provide subsidies directly to the people through their bank accounts, thus reducing leakages or delays. The subsidy on LPG cylinders will be credited directly to consumers' Aadhaar-linked bank accounts, as an advance in their bank account as soon as they book the first subsidized cylinder before delivery, so they can purchase the next cylinder at market rate until the cap of 12 cylinders per year is reached. Aadhaar is a 12-digit unique identity number that can be obtained voluntarily by residents of India, based on their biometric and demographic data.

the time needed for collecting fuelwood or unsustainable biomass. By the end of 2019 around 95% of the population had access to clean cooking. LPG is heavily subsidised and the sharp increase in LPG consumption from hitting 80 million connections in 2019 is also a substantial fiscal burden on the GoI budget. The 2018 budget allocated INR 197 698 million (USD 2.78 billion) to LPG subsidy, but it will need to increase in the 2019 budget to INR 323 150 million (USD 4.54 billion). State governments also allocate hundreds of millions to LPG subsidies.

Several major initiatives have been introduced to better target the subsidies and avoid commercial use of LPG, notably through the Pratyaksh Hanstantrit Labh (PAHAL), Pradhan Mantri Ujjwala Yojana (PMUY) and "#GiveItUp" schemes.

PAHAL, also known as the Direct Benefit Transfer of LPG scheme, sends the subsidy for the LPG purchased directly to a citizen's bank account. Key to the scheme's success has been the Aadhaar identity system, which links subsidy payments to bank accounts, and the better targeting of subsidies directly to women, which has increased women's financial inclusion and access to clean cooking. As of June 2019, 247 million LPG consumers have joined the PAHAL. By using PAHAL scheme the GoI saved around USD 8.8 billion during 2013-20.

Under the PMUY, women and BPL families receive a subsidy. Initially targeting 50 million LPG connections, the scheme reached 80 million in September 2019. PMUY had a total budget of USD 1.2 billion, which was committed by the central government. Individuals with an annual income over INR 1 million are excluded (800 000 people). The 2019 budget also confirms the goal to extend the PMUY to provide every single rural family with an electricity and a clean cooking facility.

The GoI launched the "#GiveItUp" campaign in which wealthier consumers with higher incomes are asked to volunteer to forego or "transfer" their LPG subsidy to a lower-income household. Middle-class LPG users are donating about USD 250 million annually to the effort. As of June 2019 over 10 million customers had voluntarily given it up.

The way towards a national energy policy

NITI Aayog is also preparing national energy policy strategies, the so-called National Energy Policy (NEP), in collaboration with all ministries across the GoI. Building on the earlier energy policy overviews prepared by the Planning Commission, in 2017 NITI Aayog initiated the NEP as an overarching energy policy document. The NEP aims to devise an "omnibus energy policy" to meet the four interrelated goals of achieving energy access at affordable prices, ensuring economic development of India's manufacturing capacity, improving energy security and independence, and meeting the goals of greater sustainability. The NEP sets specific targets, policies and governance/institutional arrangements on how to meet these four key objectives, notably through energy efficiency, decarbonisation measures on the demand side, and the installation, generation and distribution of renewable energy. The NEP is under consultation in 2019.

Energy data and statistics in India

India has no energy statistics law that would streamline the reporting and collection of data on energy at the central government level. In India energy data are collected and published by a number of government agencies at central and state/territory level of government. No one-stop-shop for energy data is clearly identified and mandated by law in India.

As of today, only the CEA and MoSPI have official mandates that include data dissemination. Since 2012 the Central Statistical Office has started to bring all the energy-related data together in a dedicated publication on energy statistics, including a balance presentation. However, publication dates vary widely between ministries, as well as by format. The main challenge is to gather all existing data from multiple ministries, and from private operators (which are not under any reporting obligation), to establish effective communication and increase the completeness, timeliness and user-friendliness of data dissemination. In 2018 NITI Aayog established working groups on energy data management with eight subgroups (four on the supply side and four on the demand side) to identify data gaps and design roadmaps to solve them.

The Coal Controller's Organisation collects and reports data for coal supply and some of the transformation and end-use flows. MoPNG compiles the "Indian Petroleum and Natural Gas Statistics". It reports statistics on the supply of crude oil and secondary products and some of the transformation and end-use flows, with stocks data from all refineries (except Reliance) reported to the Joint Organisations Data Initiative (JODI). MoPNG also compiles data on natural gas supply and some of the transformation and end-use flows.

Under the Electricity Act 2003, section 73, the CEA holds responsibility for power sector statistics (installed capacity for state and central government utilities). However, in practice MNRE collects capacity data, while the CEA collects generation data. The CEA and MNRE compile the statistics on electricity generation (including renewables) and trade, including at state level, as well as forecasts (NEP). MNRE also collects and publishes data on new off-grid technology capacity (number of solar pumps, solar street lights, solar lanterns, and solar home lighting systems).

India recognises the need to improve data so it can make and monitor policies better. Reflecting the gaps in the availability of data in India, end-use and TFC data remain the biggest challenge in India, notably with regard to the split by sector, fuel or activity. Such a split is essential for the design of more granular energy efficiency indicators and policies. With regard to industrial consumption, no sectoral or activity split is available. Furthermore, no reliable data are available on captive power plants (auto-consumption by industry), off-grid generation and small-scale distributed energy, with no official data on bioenergy, whether primary solid biofuels such as wood and bagasse, or other vegetal matters or animal dung, waste, liquid biofuels or biogases. (Consequently all data on bioenergy in this report are estimated by the IEA.) The consumption of traditional biomass fuels in the residential sector (for cooking etc.) is estimated to account for around two-thirds of all bioenergy supply.

With regard to public expenditure on energy research, development and demonstration (RD&D), India does not have organised data reporting or collection in place that would allow informed RD&D policy making or international benchmarking.

Assessment

During 2007-17 India's TPES increased by 55%. While energy enables the growth of the economy, it also poses immense challenges to the environment in the form of air pollution and greenhouse gas emissions. As part of its climate pledge under the Paris Agreement, the GoI aims to increase the share of non-fossil fuels in the electricity mix, which is currently dominated by coal, oil and traditional bioenergy. Coal represented 44% of TPES and its share has increased by 10 percentage points in one decade, driven by its use in power generation and industry. It is one of the sources of air pollution, among others (principally agriculture, brick manufacturing and industry).

India has made remarkable progress in improving access to energy and developing its indigenous resources. Energy demand is set to rise by another 2-3 times over the coming decades, so India faces challenges of a magnitude and character unseen in any IEA member country. The way these challenges are met will have major ramifications for other sectors, such as water, food, urban planning and transport. The GoI has launched a number of important energy policy programmes along the four priority pillars: energy access at affordable prices, improved energy security and independence, greater sustainability, and energy efficiency.

A co-ordinated national energy policy

Energy policy in India is conducted by a number of different ministries that have responsibility for their sector. Under the prime minister, NITI Aayog has an inter-ministerial co-ordinating role for energy policy. The draft NEP drawn up by NITI Aayog, currently under consultation, should be swiftly adopted to guide policy making across government. To strengthen co-ordination, a permanent framework for the government's long-term energy policy is highly desirable to create visibility for all stakeholders in the energy sector.

Energy policy is a concurrent competence matter in India, with significant authority vested in the states for setting their own mandates, standards and energy subsidy programmes. Differences in the resource base and economic development contribute to diverse policy approaches across states, contributing to the complexity of energy policy co-ordination for the GoI. The role of the GoI is critical in reviewing and ensuring compliance, and supporting states in implementation through collaborative approaches. The implementation and enforcement of policies and measures could therefore be improved.

Good quality and timely energy data is fundamental for monitoring energy policies, reviewing their progress and enforcing their implementation. The GoI has identified the critical importance of energy data and is taking action to improve energy data collection and dissemination. The IEA welcomes the recent progress in the long-standing bilateral relationship between India and the IEA on energy statistics, which has led to the creation of cross-ministerial working groups with NITI Aayog. Work is ongoing to centralise data collection and support the work of MoSPI to establish the country's energy balance.

Access to electricity and clean cooking

Achieving universal energy access at affordable prices and on a 24/7 basis by 2022 is a top priority for the GoI and the states. Over recent decades India has made significant progress in village electrification and providing electricity connections to households. After reaching 100% village electrification in 2018, within only a year, in March 2019, the GoI declared it had achieved the full electrification of almost all households, which is a major milestone for India and the world. The IEA commends the GoI for this result, which is an achievement of historic proportions, given the scale of the challenge. In total, over half a billion people gained access to electricity during the past 17 years, reflecting a strong and effective policy push.

Based on political leadership and strong institutions with the capacity and mandate to deliver electrification programmes, the GoI has co-funded network upgrades and extensions through the DDUGJY, the Saubhagya scheme and the IPDS (in urban areas). More recently it has created programmes to promote mini-grid and stand-alone solar home systems to deliver access to some of the hardest-to-reach homes. India has a national access to electricity rate of above 95%, according to the latest IEA data. The next step will be to ensure quality of access on a 24/7 basis and access for households unwilling to get connected.

Equally, the GoI has made strides to phase out traditional use of biomass and provide clean cooking fuel to every household, through targeted subsidy schemes (PAHAL, PMUY). The PMUY scheme has resulted in a "Blue Flame Revolution" with 80 million new LPG connections as of September 2019, improving health, especially for women and children, by reducing exposure to indoor air pollution and eliminating time collecting fuelwood. This has been a major success for India and the scheme is exemplary in the way it is implemented, including the targeted approach of the PAHAL programme. The results provide major health and economic benefits to society. Government data show that households that have received a free connection and the subsidy via the PAHAL programme buy around 3.5 cylinders of LPG per year, and are displacing around one-quarter of the fuelwood used in the households that have taken up the scheme, or 6% of total biomass used in India's households (IEA, 2018).

Nevertheless, in light of negative impacts on human health, productivity and the environment, there is a need to accelerate the transition to modern and efficient cooking. The IEA welcomes the plans of the GoI to promote the fuel switch to solar thermal and solar PV cooking applications, which can be used both off- and on-grid and provide cleaner alternatives, and will further boost access, health and economic benefits.

Economic efficiency

The GoI is implementing an impressive programme of reforms, targeting more sustainable and efficient taxation and subsidies, financial inclusion, trade, and access to energy, amongst other goals. This has significantly improved the broader investment climate, strengthening India's relative position in attracting foreign direct investment and the ease of doing business. The GoI launched the Make in India programme to help increase the share of manufacturing as a proportion of GDP from 16% to 25% by 2022, and to create 100 million additional jobs in industry. The development of technology and innovation will be a key driver for India's economic growth.

Impressive energy efficiency programmes have so far focused on industry and created an energy service market in that segment. The use of green bulk procurement (for instance of LED light bulbs) has helped accelerate energy savings. The IEA welcomes this progress. There is an opportunity for the central and state governments to accelerate energy efficiency implementation across the public sector (buildings, transport) and all end uses by concerted action to remove barriers and help create market demand for energy services. This could include facilitating access to equity and venture capital, risk mitigation through, for example, guarantee schemes and by providing incentives both for energy service companies and customers.

India made significant progress in phasing out direct and indirect fuel subsidies. The GST will be gradually subsuming fuel taxes and subsidies across India. Electricity and natural gas remain outside of the GST. This leaves room for more effective price signals. A uniform

GST would enable a greater level playing field – notably electricity and natural gas need to be brought under the GST to provide a level playing field between coal and gas. Bringing natural gas within the GST will also enable the greater penetration of gas as an industrial fuel and fuel for power generation, and a feedstock for fertiliser and petrochemicals production, LPG and city gas distribution.

The GoI has embarked on a course of reducing fossil fuel subsidies, which the IEA welcomes. A good example of subsidy reform is the reduction and better targeting of LPG support. To control subsidies, the GoI introduced the Direct Benefit Transfer of LPG (PAHAL) scheme and launched the #GiveItUp campaign, which was successful in motivating LPG users who can afford to pay the market price to voluntarily surrender their LPG subsidy – leading to an amount of USD 250 million being returned to the budget annually. These two combined have saved some USD 9 billion in subsidies during 2013-20. While LPG represents strong progress for the health of families, the government could consider stimulating a transition towards super-efficient induction cook stoves that can be coupled with nominally sized off-grid solar PV and by continuing to strengthen electricity supply infrastructure in rural areas.

The government should continue phasing out indirect subsidies to ensure that retail energy prices reflect the full costs of energy, leading to a more efficient allocation of resources and enabling a greater investment in energy efficiency from the private sector. To avoid negative impacts on certain customer segments, a phase-out could be coupled with targeted energy efficiency measures to reduce energy costs for these groups. The SERCs are already working towards roadmaps to achieve cost-reflectiveness of electricity prices.

The financial health of the energy sector remains of critical importance, given the large investment needs. The Reserve Bank of India's revised stressed assets framework appears to provide more flexibility for the resolution of stressed assets after the Supreme Court annulled the strict one-day-default circular of February 2018.

The DISCOMs face the main burden from stressed assets. While the UDAY scheme has been successful in bringing down the cost of financing and achieving greater efficiency, without structural reforms of the DISCOM tariffs new bail-outs are nonetheless likely in the future. The GoI announced in 2019 stronger conditionality of public loans/grants awarded to DISCOMs for network investment.

India's energy sector is dominated by large PSUs in which the GoI holds majority stakes. The PSUs play a major role in India's economy. Over time, the GoI has taken actions to improve the governance of the PSUs to foster transparency, accountability and the professionalism of the boards by bringing in independent directors from the private sector and empowering boards with greater decision-making authority. Moving towards a level-playing field for all entities in all energy sectors will further attract private investment. The opening of coal mining to commercial actors is a promising development.

Energy security

In respect of energy security, much attention has been given to enhancing oil security through the diversification of sources and supply routes and creating emergency stocks. The IEA very much welcomes the excellent co-operation on oil emergency policy it has experienced with India and welcomes further deepening of this co-operation.

With the rising importance of natural gas, renewables and greater electrification in global energy supply, the IEA promotes the significant broadening of the concept of energy security to include gas security and electricity reliability. The same trends will affect India, even when the share of gas and electricity are still somewhat lower, albeit rising all the same. If gas becomes more relevant in the energy mix, then the risks and costs of possible disruption will rise. The same is true for electricity, where high levels of reliability become increasingly relevant in a digital society.

Sustainability

The government has embarked on an ambitious policy to boost renewable electricity, with a target of 175 GW capacity by 2022. Under its NDC, India targets a share of non-fossil-based capacity in the electricity mix of more than 40% by 2030 and a reduction in the emissions intensity of its GDP of 33-35% by 2030 over 2005. Recently the GoI has indicated ambitious new targets for renewables capacity in the region of 450 GW. In addition, the GoI is promoting hydropower as a source of flexibility and grid stability (it is now categorised as renewable energy and can be supported under hydro purchase obligations). The GoI expects 21 GW of new hydropower projects to be developed by 2030, requiring an investment of about USD 31 billion.

India's energy sector is transitioning to greater sustainability. As a result of the country's proactive and sustained actions on climate change mitigation, the emissions intensity of India's GDP has reduced by around 20% over the period 2005-14.

Energy efficiency is receiving more attention, with standards and codes being set for industry, buildings and appliances. Renewables are already providing a rising share of the electricity mix. The policy of competitive bidding has delivered lower renewable energy prices than anybody had expected. India has vast renewable resources, which are great assets for building a sustainable energy future. The new GoI ten-point economic programme for the next decade indeed places the emphasis on clean air, water and soil.

India's energy transition offers very large co-benefits, notably for public health by limiting air pollution, a big challenge in all major cities and a source of future health concerns with growing industrial production and manufacturing. The GoI has ruled out deploying new coal capacity up to 2027 (beyond plants still under construction) and aims to close the oldest most inefficient coal plants in the country. However, the GoI estimates that it will need to rely on coal to satisfy the bulk of the country's peak electricity demand. It has announced plans to build new coal plants after 2027 for the 2030 horizon to foster an optimal generation mix with higher shares of renewables and energy storage. The increase in the energy efficiency of coal production and use, and the full implementation of air pollution standards for power plants, are fundamental for the longer-term transition.

Energy data and statistics

India and the IEA benefit from a longstanding bilateral relationship, first formalised in 1998 with the signing of a Declaration of Co-operation, which covered energy security and statistics, and three Joint Statements under IEA Association. In 2016 NITI Aayog and the IEA signed a Statement of Intent to enhance co-operation in many fields, including forecasting and data. The IEA Energy Data Centre and the GoI are collaborating closely, through MoSPI and NITI Aayog, on annual energy statistics to establish the country's energy balance and improve India energy data collection and dissemination. The IEA supports MoSPI's work to help centralise data collection and to improve templates used to collect data from ministries to establish the country's energy balance. The IEA and MoST collaborate under a memorandum of understanding to improve the availability and collection of data on energy RD&D.

Recommendations

The Government of India should:

- Adopt a national energy plan to set a long-term framework for all stakeholders across the energy system, which also identifies future energy infrastructure investment needs and provides an integrated approach that fosters:
  - energy security across oil, gas and electricity sectors, based on global good policy practice
  - full access to affordable, clean and reliable energy
  - energy efficiency across the economy
  - sustainability of the energy system, notably through system integration of variable renewable energy, clean mobility and clean air
  - strong co-ordination of energy policy across central government and alignment between the central and state governments on key energy policy matters, notably on electricity market design and renewable targets.
- Continue to rationalise pricing methodologies, subsidies and cross-subsidies across the energy sector.
- Continue reducing and consider phasing out fossil fuel subsidies through the reform of the LPG scheme in favour of cleaner fuels.
- Strengthen monitoring, implementation and compliance with policies and regulations.
- Improve the collection, consistency, transparency and availability of energy data across the energy system at central and state government levels.

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3. Energy and sustainable development

Key IEA data

(2017)

Energy-related CO_2 emissions:

CO_2 emissions from fuel combustion: 2 162 Mt CO_2, 6.6% of global total, up 71.4% since 2007, when it represented 4.4% of global total

CO_2 emissions by fuel: coal 69.7%, oil 26.8%, natural gas 3.4%, other 0.1%

CO_2 emissions by sector: power generation 50.9%, industry 26.1%, transport 13.5%, residential 3.9%, other energy 1.5%, other 4.1%

CO_2 emissions per unit of GDP: 0.26 kg CO_2/USD PPP (IEA average 0.23).

CO_2 emissions per capita: 1.6 t CO_2 (IEA average 9.0 t CO_2)

Overview

The energy sector plays a critical role in both meeting sustainable development objectives and reducing environmental externalities in India. The country is vulnerable to climate change impacts and is exposed to growing water stress, storms, floods and other extreme weather events. Adaptation and resilience of the energy system to these conditions should receive higher political priority. Moreover, India attaches great importance to the Kigali Amendment to the Montreal Protocol on ozone-depleting substances, given its soaring cooling demand. India acknowledges that early action to address air pollution and emissions will reduce future adaptation needs.

Providing secure, affordable and sustainable energy to all is an important policy priority in India, and major progress has been made towards the United Nations Sustainable Development Goals (SDGs), notably SDG7 on energy. India has been addressing energy-related environmental pollution since the 1980s, including issues related to air, water and land, and energy sector waste, with ground-breaking legislation under the Air (Prevention and Control of Pollution) Act. Reducing the health impacts of energy production and use and air pollution (now part of SDG3) is a key priority and the GoI has adopted comprehensive and stringent rules for the power and transport sectors. Climate change (SDG13) is a driver of the policy agenda on which India shows strong international leadership. The country's share of global energy-related carbon dioxide (CO_2) emissions has increased by more than two percentage points since 2007, to account for 4.4% of the global total, with emissions rising by around 70% in absolute terms. India has submitted a

Nationally Determined Contribution (NDC) under the Paris Agreement with considerable mitigation efforts taking into account India's low per capita emissions and its development priorities.

Energy, environment and sustainable development: An integrated policy response in the context of SDGs

The way energy is produced and consumed is key to delivering India's sustainable development objectives. The country's substantial and sustained economic growth will require extensive energy resources. Energy policies play an essential role in driving economic growth and providing access to affordable modern energy services as a prerequisite for eliminating poverty and reducing inequalities.

At the same time, energy is a major source of negative environmental externalities, such as air pollution that causes severe health problems in India and around the world, and it is also the principal source of greenhouse gas (GHG) emissions, making the energy sector a key component in climate change adaptation and mitigation.

The SDGs, unanimously adopted by the United Nations, provide an internationally recognised framework for key development objectives, including specific targets to measure progress. At national level, India has already set itself ambitious targets in several SDGs areas, such as economic progress and reducing poverty, inclusiveness and sustainability (see also RIS [2016]). The scope of sustainable energy is primarily covered by SDG7, but other SDGs, notably SDG3 on health (including the severe impacts of air pollution) as well as SDG13 on climate, are closely linked to the energy sector.

The three key targets that embody the SDG7 objective to "ensure access to affordable, reliable, sustainable and modern energy for all" are also central to India's current energy challenge of: 1) universal access for all, 2) ambitious scale-up of renewable energy and 3) enhanced energy efficiency.

To be successful, a sustainable energy transition needs to simultaneously address the interlinked challenges of economic development, energy security and enhanced economic competitiveness, while at the same time fulfilling sustainable development objectives including promoting energy access, reducing air pollution and preventing climate change.

Air quality, climate adaptation and mitigation, and energy access challenges should therefore be addressed simultaneously in an integrated response. In particular, air quality and climate policies require some of the same set of response measures, creating opportunities for synergies, cost-effectiveness and complementarity of policy combinations. This can accelerate the clean energy transition and the achievement of multiple policy objectives.

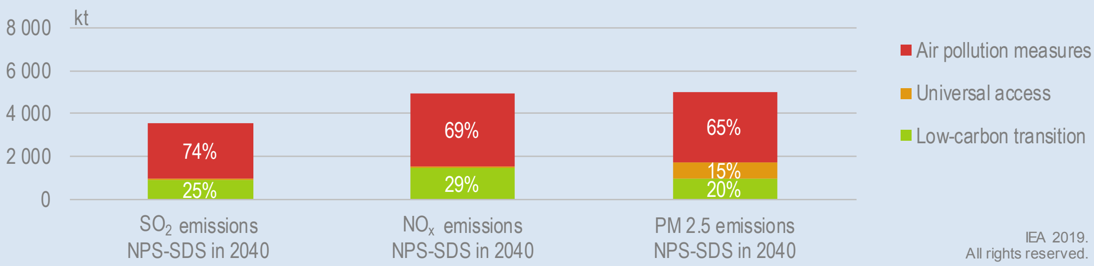
The following sections discuss progress made in India with regard to these three pillars of sustainable development. The sections also outline future trends, based on stated policies alone.

Box 3.1 Benefits of an integrated energy sector response to sustainable development

Given the multi-faceted nature of the energy transition, coherent packages of policies are needed to achieve the necessary rate of change across the energy system, in all subsectors, impacting all key actors. A critical strategy to make this politically feasible – as well as cost-effective – is to seek out policy synergies and integrated approaches that simultaneously deliver on the various socio-economic goals of energy security and affordability, air pollutant and GHG emissions reductions (IEA, 2017a).

To highlight synergies that can be exploited, International Energy Agency (IEA) analysis shows that in an integrated approach to energy-related SDGs, reductions in air pollutant emissions can be achieved by policies targeting all three pillars of sustainable development. Policies aimed at enhancing universal energy access *and* reducing CO_2 emissions could contribute well over 30% of reductions in nitrogen oxides (NO_X) and PM 2.5 emissions (particulate matter) and 25% of reductions in sulphur dioxide (SO_2) emissions (Figure 3.1). Such a pathway therefore confirms that India can be successful in achieving substantial reductions in energy-related CO_2 emission, as it joins up the air pollution policy agenda with delivering on energy access and climate change objectives.

Figure 3.1 Contribution of sustainable development policies towards air pollutant emissions reductions in India



Note: kt = thousand tonnes.

Source: IEA analysis based on IIASA data.

Investment in energy efficiency and renewables is an effective low-carbon transition strategy as it entails strong co-benefits, reducing air pollutants by about 25% for SO_2, 30% for NO_X and 20% for PM 2.5, as illustrated in Figure 3.1. Equally, achieving universal access to *modern* energy by 2030, when fostering clean cooking, can achieve a reduction in PM 2.5 of nearly 15%. This relies on clean cooking, which aims to abolish the use of solid fuels such as traditional biomass. Targeted air pollution standards with post-combustion control technologies, such as scrubber and filters, for coal-fired power plants are cost-effective. Given the long-lived nature of energy sector infrastructure, the use of these measures is effective both at cutting air pollutant emissions in the near term and facilitating their long-term decline.

Source: IEA (2017a), *Policy Packages for Clean Energy Transition,* www.iea.org/publications/insights/insightpublications/real-world-policy-packages-for-sustainable-energy-transitions.html.

Ensuring sustainable energy for all: SDG 7

India is making good progress in its national efforts to meet the various SDG 7 targets. These include to measures to ensure universal access to modern energy, including electricity and clean cooking (SDG 7.1), to foster the deployment of renewables and to increase the share of renewable energy consumption in the global energy mix (SDG 7.2) and to double the rate of energy efficiency improvements (SDG 7.3).

Access to electricity and clean cooking: SDG 7.1 progress and outlook

Electricity access

Universal household and village electricity access[1] has been a key priority for the Government of India (GoI) for the past 15 years (with particular focus on rural areas). In April 2018 the GoI announced that India had achieved its goal of providing electricity to every village in India (600 000 villages). A year later, in April 2019, the GoI announced that it had effectively connected all the households that were willing to do so (26 million), according to the latest government data.[2]

The Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and the Saubhagya schemes are the two main government policies to respectively complete provision of electricity access for every village and household. The introduction of the Saubhagya scheme[3] in September 2017 helped accelerate the rate of household electrification, connecting the last mile. Over 95% of people who have gained electricity access in India since 2000 have done so as a result of grid extension, according to the IEA.

Coal power has been used to supply about 75% of the new electricity access since 2000, with renewable sources accounting for around 20%. Enhancing the use of clean energy will play an important role in ensuring that electrification objectives are in line with delivering air quality improvements as well as reducing GHG emissions.

The access paradigm is, however, changing. Recent mini-grid policy developments show promising signs for enhancing the role of renewables in ensuring electricity access. A draft national renewable energy mini-grid policy was published in 2016 with the aim of developing 10 000 micro-grids and mini-grids with a combined capacity of 500 megawatts.

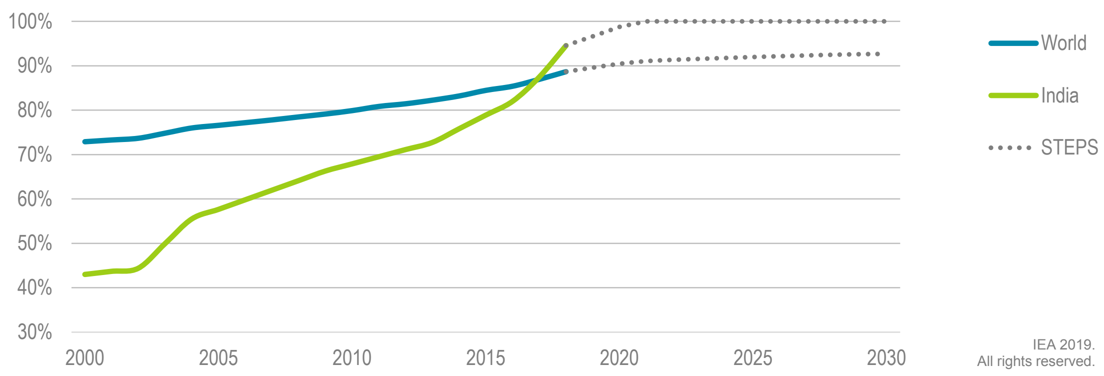
Based on announced policies in India, the IEA estimates that rapid progress will continue, with the entire population of India benefiting from uninterrupted access to electricity (Figure 3.2).

[1] The electrification rate can be measured in different ways. India has dual electrification targets that focus on both electrifying villages (a village is considered electrified if 10% of households and community services have access) and households. IEA methodology, however, focuses on the share of the population with access to electricity in line with the UN SDG tracking framework.

[2] India's central online tracking of electricity access can be found at: http://garv.gov.in/dashboard.

[3] Electricity connection to a household comprises drawing a service cable from the nearest pole to the household premises, installation of an energy meter, wiring for a single light point with light-emitting diode (LED) bulb and a mobile charging point. In cases where an electricity pole is not available nearby, the erection of an additional pole along with conductor and associated accessories is also covered. More information is available at: https://saubhagya.gov.in/.

Figure 3.2 Proportion of population with access to electricity, 2000-30



Note: STEP = Stated Policies Scenario, a projection based on existing policy frameworks and announced policy intentions

Sources: IEA (2019a), *World Energy Statistics 2019*, www.iea.org/statistics/; IEA (2019b), *World Energy Outlook 2019*.

Clean cooking

India is progressing at a slower speed towards the second SDG 7.1 objective – access to clean cooking. Indoor household air pollution from solid fuel combustion for cooking has considerable negative health impacts.[4] The share of the population in India using biomass and kerosene declined by 16 percentage points between 2011 and 2018, with exactly half of the total population now using cleaner fuels, such as liquefied petroleum gas (LPG).

GoI programmes to support clean cooking focus on increasing the usage and financing of LPG, with the explicit aim of empowering women and improving their health. The Pradhan Mantri Ujjwala Yojana (PMUY) scheme is designed to provide women living below the poverty line with a free LPG connection, subsidised refills and courses on how to use LPG. It has reached tens of millions of women in India over just a few years. The GoI pledged to provide 50 million free LPG connections by 2019, but actually achieved 80 million (which were targeted for 2020) already in 2019. As explained in detail in Chapter 2 on general energy policy, the GoI adopted a range of important policies to better target the subsidies to those who need them, including the Pratyaksh Hanstantrit Labh (PAHAL) scheme and “#GiveItUp”.

However, in 2018 an estimated 680 million people in India still do not have access to clean cooking solutions and primarily rely on biomass for cooking (IEA, 2018b). Based on stated policies, IEA projections indicate that the share of the population relying on the use of traditional biomass for cooking will continue to decline, dropping initially to around 500 million, a third of population in 2030, and a quarter by 2040. In spite of this progress, traditional cooking still imposes a substantial burden on women, in particular, who spend on average nearly 1.5 hours per day collecting fuelwood, equivalent to more than 100 billion lost working hours (IEA, 2017b).

[4] Impacts of indoor air pollution in India are estimated at 670 000 premature deaths according to the Global Burden of Disease Study 2017 (GBD, 2019).

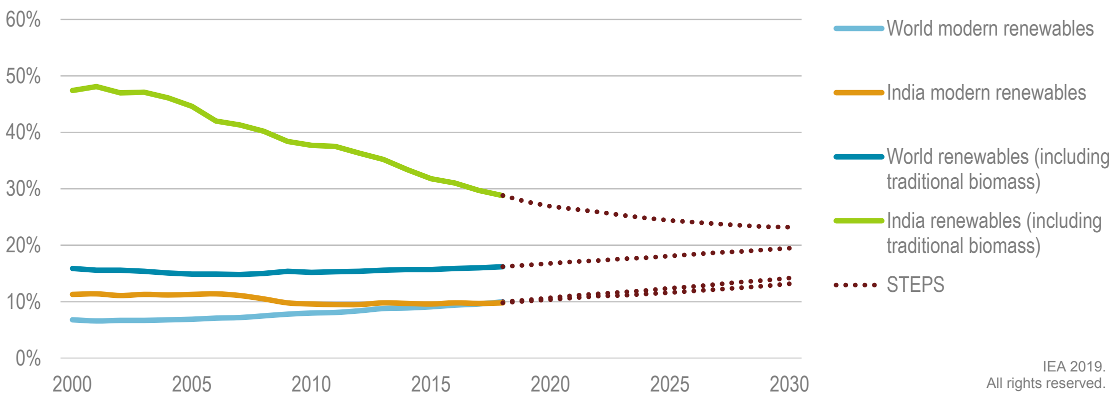
Renewables: SDG 7.2 progress and outlook

The official SDG 7.2 tracking methodology accounts for all renewables, including the use of traditional biomass. On this basis, the share of all renewables in India's total final consumption (TFC) in 2018 stood at 28.8%, as traditional biomass still plays an important role, notably for cooking. However, the use of traditional biomass for cooking is a major source of indoor air pollution.

Only modern renewables (outside traditional biomass) will play a role in delivering sustainable development and energy access for isolated areas (see below for further analysis of air pollution and climate change as well as Chapter 5 on renewable energy). The share of modern renewables (which includes hydro but excludes traditional biomass) accounted for 9.8% of TFC in 2018, at the same level as 10 years ago (as energy demand has been on a steep rise).

Reflecting the extensive growth potential for modern renewables, the government set a renewable capacity goal of 175 GW by 2022, targeting 60 GW of utility-scale solar photovoltaic (PV), 40 GW of rooftop solar PV, 60 GW of wind power, 5 GW of small hydro and 10 GW of bioenergy. It plans for 227 GW by 2022 (114 GW of solar, 67 GW of wind, 31 GW of floating solar and offshore wind, 10 GW of bioenergy and 5 GW of small hydro). By 2019 India had a total installed renewable electricity capacity of 80 GW, and in the same year India announced its ambition to increase its renewable energy capacity to 450 GW.

Figure 3.3 Modern renewables and renewables including traditional biomass, share of TFC, 2000-30



Note: STEP = Stated Policies Scenario, a projection based on existing policy frameworks and announced policy intentions.

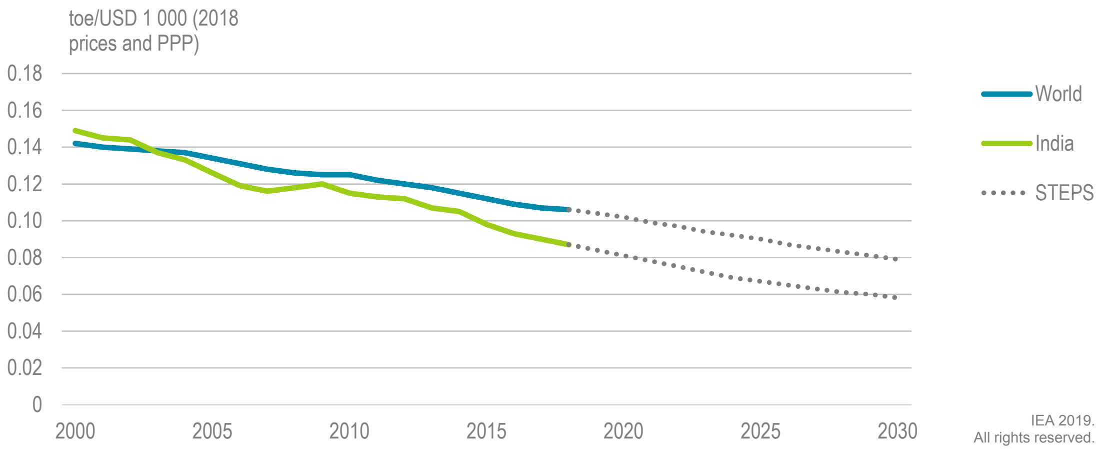
Sources: IEA (2018c), *Renewables 2018*, IEA (2019b), *World Energy Outlook 2019*.

IEA projections based on India's stated policies show the share of modern renewables rising to 13% of TFC by 2030 and 17.5% by 2040. The share of traditional biomass in TFC is expected to decline from 22% today to 12% in 2030 (and 8% in 2040). Electricity generation from renewables sees considerable growth, from 18% today to around 45% of electricity by 2040, while the share of coal declines from 74% today to 46% in 2040. This calculation is based on India meeting its renewable capacity target of 175 GW by 2022, and seeing capacity growth to almost 430 GW by 2030 and 800 GW by 2040. With this growth, India will fulfil the SDG 7.2 objective of substantially increasing the share of renewables in its energy mix.

Energy efficiency: SDG 7.3

Energy intensity in India, defined as the ratio of primary energy supply to gross domestic product (GDP), stood at 0.09 toe/USD 1 000 (2018) in 2017, well below the world average of 0.107 toe/USD 1 000 (Figure 3.4).

Figure 3.4 Energy intensity (TPES/GDP) in India, the region and the world



Notes: TPES = total primary energy supply; STEP = Stated Policies Scenario, a projection based on existing policy frameworks and announced policy intentions

Source: IEA (2019b), World Energy Outlook 2019; IEA (2019c), Energy Efficiency 2019.

A decrease in energy intensity (Total Primary Energy Demand TPED/GDP) of 27% over the past ten years has taken place against the backdrop of a near doubling of India's primary energy demand, driven by strong economic growth rates of 6.8% on average since 2010. The gradual decoupling of energy use and economic growth in India resulted from energy efficiency improvements and, to smaller degree, from structural changes in its economy. The IEA estimates that energy efficiency improvements in India since 2000 have avoided an additional 15% of energy use in 2018 (IEA, 2019c).

Efficiency gains were largely achieved in the industrial and service sectors, as well as in residential buildings. IEA analysis confirms that such efficiency improvements avoided nearly 300 Mt CO_2-eq in emissions or 14% more carbon dioxide (CO_2) emissions in 2018, 8% of more oil and 12% of more gas imported that year, while structural changes in the economy were responsible for only avoiding 1% more energy use in 2018. These structural changes entail the shift of economic activity from energy-intensive industry sectors to less-intensive manufacturing and service sectors. However, total energy efficiency improvements were almost completely offset by other factors that boosted energy use, specifically increases in residential building floor area and appliance ownership, shifts to less-efficient modes of transport, and decreasing vehicle occupancy rates.

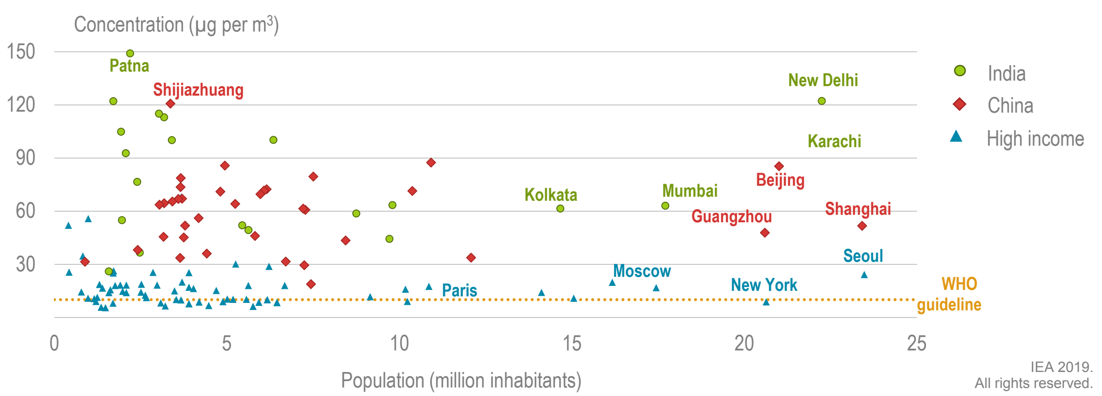
The GoI has introduced a range of new policy measures to further improve the energy efficiency of its economy. IEA estimates suggest that these will result in an energy intensity reduction of over 30% by 2030 and almost 50% by 2040. Given that announced policies result in an estimated improvement in energy efficiency of 3.3% per year until 2030, the GoI is on track to surpass the global SDG 7.3 of doubling the global rate of improvement in energy efficiency to 2.7% per annum.

Energy and air quality: SDG 3

Air pollution is a major cause for concern in India and a key policy priority for the government. Combinations of various air pollutants from a diverse range of sources have led to very unhealthy levels of air pollution concentrations in certain regions, in particular major urban areas. The energy sector is the largest source and therefore also the key component of the solution for the air pollution crisis in India. Combustion of fossil fuels (in power, transport and industry) and bioenergy are the two key activities releasing air pollutants and causing negative health impacts. Non-energy-related sources, such as dust from construction of buildings and roads or fallow fields, also play an important role. Episodes of high concentrations of air pollutants can also be exacerbated through particular non-energy sector related events, such as burning of crop residue in specific seasons, the pollution from which can migrate from rural to urban areas. This chapter focuses primarily on the air pollutants most characteristic to energy sector activities, including NO_X, SO_2 and PM 2.5.

As many as 10 of the top 20 most polluted cities in the world are located in northern and north-western India, exceeding World Health Organization (WHO) recommended average annual concentrations by on average 10 times (Figure 3.5).[5] In 2017 air pollution caused around 1.2 million premature deaths in India (12.5% of the total), with household air pollution estimated to have been the cause of over 480 000 of them, and outdoor air pollution attributed to an estimated additional 670 000 (GBD, 2019). Coal used in power generation contributed 7.6% of all PM 2.5.

Figure 3.5 Average annual outdoor PM 2.5 concentrations in selected urban areas, year



Notes: µg = microgramme; m³ = cubic metre.

Sources: Adapted from IEA (2016), *Special Report on Energy and Air Pollution*, drawing on WHO (2016) *Global Urban Ambient Air Pollution Database*, www.who.int/phe/health_topics/outdoorair/databases/cities/en/; Demographia (2015), World Urban Areas, http://www.demographia.com/db-worldua.pdf, for population; country groups per income based on World Bank (2016), https://databank.worldbank.org/reports.aspx?source=world-development-indicators

Current status of air pollutants

Particulate matter is the main concern as concentrations exceed national standards for PM 10 and PM 2.5 in many of the monitored locations.[6] NO_X are becoming increasingly

[5] The WHO has issued air quality guidelines for a number of air pollutants, including SO_2, NO_2, PM and ozone. The guidelines apply worldwide and are based on expert evaluation of the scientific evidence.

[6] The National Ambient Air Quality Standards, issued on 18 November 2009, are as follows: for PM 10, 60 µg/m³ annually and 100 µg/m³ over 24 hours; PM 2.5, 40 µg/m³ annually and 60 µg/m³ over 24 hours; for NOx, 40 µg/m³ annually and 80 µg/m³

problematic, with measurements indicating concentrations that approach or exceed the standards in a growing number of locations. SO_2 concentrations are a particular issue in certain hotspot areas with many power plants and other industrial facilities that combust or process coal.

NO_X emissions from energy primarily arise in the transport sector, accounting for almost 40% of the total, followed by the power sector (31%) and the industrial and transformation sectors (20%). Most of the NO_X emissions in transport come from road transport, mainly from heavy-duty vehicles (HDVs). Mass transport modes, such as buses and rail, are important mobility modes in India, although there is a trend towards greater individual motorisation (as in other emerging economies and many industrialised countries). Passenger vehicle ownership in India has nearly tripled over the last decade, resulting in a strong increase in tailpipe and non-exhaust emissions and damage to human health: around three-quarters of total passenger vehicle kilometres in India today are driven in urban areas. Coal power generation and coal use in heavy industry are also major sources of NO_X emissions.[7]

The power sector remains the source of more than half of SO_2 emissions from energy-related activity (Figure 3.6), despite successful efforts to reduce it (see below section on the Environment Protection Amendment Rules [EPAR] for the power sector). The power supply's 75% reliance on coal and the characteristics of the coal used are the main drivers of these emissions. While Indian coal is relatively low in sulphur, it has high ash content,[8] which also affects the level of PM emissions and, if not adequately controlled, results in elevated dust emissions.[9] While around a quarter of the population lives in close proximity to a coal plant, less than 5% live near a plant that is not fitted with dust control equipment and this situation is expected to improve.

The main source of PM 2.5 emissions is the buildings sector, accounting for nearly two-thirds of India's total. Around two-thirds of the Indian population today still use solid fuels as their primary fuel for cooking, and this is the key driver of PM 2.5 emissions. In rural areas biomass use for cooking and heating represents 85% of the energy supply. Its use is, however, on the decline in urban areas where only one-quarter of households use solid biomass for cooking today, down from a 50% share 25 years ago. The adverse consequences of the use of biomass for cooking fall predominately on women and children, who suffer the worst health effects of the smoky indoor environment. Cooking is not the only domestic activity in India that contributes to household air pollution. People without reliable or universal access to electricity supply use alternatives for lighting purposes. Biomass, torches, candles and solar lamps are used by only around 1% of the population, while kerosene lamps are used on a regular basis by 30% of Indian households

over 24 hours; for SO_2, 50 µg/m³ annually and 80 µg/m³ over 24 hours. Standards set by the Central Pollution Control Board, www.indiaenvironmentportal.org.in/files/826.pdf; www.arthapedia.in/index.php?title=Ambient_Air_Quality_Standards_in_India; and www.indiaenvironmentportal.org.in/files/file/Air%20Quality%20Index.pdf.

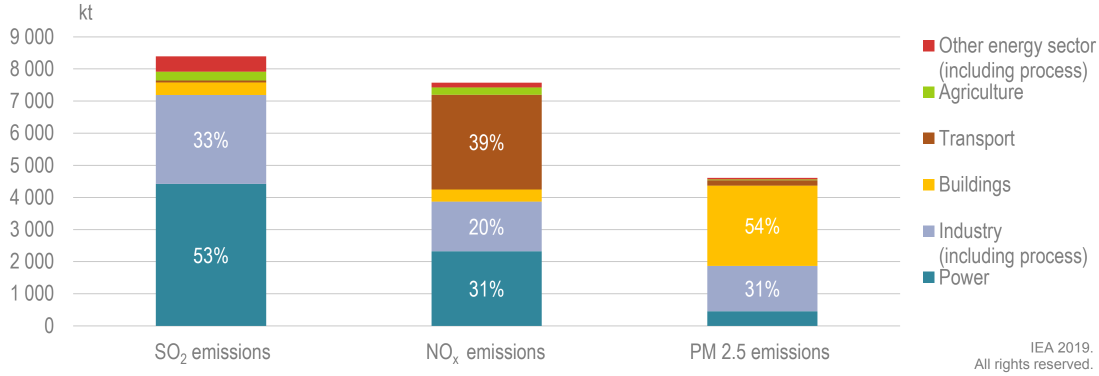
[7] www.atmos-chem-phys.net/18/8017/2018/acp-18-8017-2018.pdf.

[8] Three-quarters of current coal production has ash content of 30% or more, with some of the highest-ash coals approaching 50%.

[9] Thermal power plants are, according to the Environment Protection Amendment Rules (EPAR) of 2015, required to operate electrostatic precipitators that limit the particular matter to the revised environmental norms.

(around 80 million). Smoke from kerosene contains a high level of PM, especially black carbon.

Figure 3.6 Energy-related emissions of major air pollutants (SO_2, NO_X and PM 2.5) by sector, 2018



Sources: IEA (2019b), *World Energy Outlook 2019*, based on IIASA.

Air quality policy framework

Under the stewardship of the Ministry of Environment, Forest and Climate Change (MoEFCC), India has promulgated comprehensive air pollution regulation over many years. The Air (Prevention and Control of Pollution) Act (1981) is the main legislation that addresses the prevention, control and abatement of air pollution. The Central and State Pollution Control Boards (CPCB/SPCBs) and the Environmental Pollution Control Authority (EPCA) were established to enforce regulation.

Since the mid-1980s, ambient air quality has been monitored across the country under the National Air Monitoring Programme, which was initiated by the CPCB. In 2015 Prime Minister Shri Narenda Modi launched the National Air Quality Index, providing real-time monitoring of air pollution, and a graded response action plan (known as GRAP), laying out actions that need to be taken if the air quality deteriorates, especially in the 100-odd cities with the worst problems. A recent (2018) initiative is the National Clean Air Programme (NCAP). As of August 2018, there are 134 continuous ambient air quality monitoring systems and 703 manual ambient air quality monitoring stations in service, covering 307 cities in 29 states (GoI, 2019). India therefore has a long and established history of monitoring, assessing and tackling air pollution.

Transport sector

The CPCB set the first emission standards in the mid-1980s for gasoline and diesel vehicles. The nationwide regulatory standard for light-duty vehicles (LDVs) and HDVs placed on the market since 2017 is Bharat Stage IV, comparable to Euro 4. The GoI has announced a plan to move to Bharat VI nationwide for LDVs and HDVs alike by April 2020, essentially skipping Bharat V. Implementing Bharat VI will limit gasoline and diesel fuels to 10 parts per million of sulphur, bringing India into line with the global leaders in fuel sulphur standards as early as 2020.

Box 3.2 A brief history of environmental laws and courts in India

India has a unique judicial stewardship of environmental rules and regulations enforced through environmental courts, also known as "green courts". The courts are at the forefront of promoting environmental standards, following the 1984 Bhopal catastrophe, a devastating leak of methylisocyanate from a plant in the city of Bhopal which led to the death of over 3 500 people, and also caused severe contamination of soil and groundwater. In the 1970s legislation in India started evolving to include and protect more aspects of the environment. In 1972 the Indian Parliament moved to enact new laws, including the Wildlife Protection Act 1972 and Water (Prevention and Control of pollution) Act 1974. Later in the early 1980s, the Forest Conservation Act 1980 and the Air (Prevention and Control of Pollution) Act 1981 were also passed (Nyati, 2015).

Until the mid-1980s, however, these laws were not appropriately enforced, in part due to a lack of capacity within institutions and in part due to developmental objectives that prioritised job creation and industrialisation. Several deficiencies in India's laws and institutions were laid bare after the 1984 Bhopal tragedy; it triggered judicial and legislative action. Legislative action included the passing of the Environment (Protection) Act of 1986, under which public interest groups and citizens could act against polluters. Until that time, only the state was able to take action. The Air Act and Water Acts were also amended to enable citizen action against polluters. These amendments forced the Pollution Control Boards to disclose their internal reports to citizens seeking to prosecute a polluter (Nyati, 2015). In 1988, on the backs of the Forty-Second Constitutional Amendment that was enacted in 1976, the Supreme Court interpreted the fundamental right to life and personal liberty under Article 21 to include the right to a healthy environment (PIB, 2014).

Over time, the complex multi-disciplinary nature of environmental cases was recognised by the legislature. In 1997 the National Environmental Appellate Authority (NEAA) Act was passed to hear appeals under the Environment (Protection) Act. The courts could refer scientific and technical aspects for investigation and opinion to expert bodies, including the Appellate Authority (Rosencranz, Sahu and Raghuvanshi, 2009).

In 2010 the National Green Tribunal (NGT) Act was passed, establishing a court exclusively for cases under seven environmental laws including the Air Act, Water Act, and Environment (Protection) Act and which could specialise in technical environmental matters. The NGT replaced the NEAA, and India became the third country in the world (after Australia and New Zealand) to have a dedicated green court. The NGT is not bound by the procedure laid down under the Code of Civil Procedure 1908, but is instead guided by principles of natural justice. The NGT is also not bound by the rules of evidence, which makes it easier for conservation groups to present their case at the tribunal. Unlike the mainstream court system where cases may be delayed owing to a backlog of cases, the NGT is mandated to dispose of applications or appeals within 6 months of their filing as and where possible. The tribunal applies the principles of sustainable development, the precautionary principle and the polluter pays principles while passing orders. The NGT has since been responsible for several judgements to mitigate environmental damage, including judgements on agricultural residue burning and curbs on traffic to reduce air pollution.

Sources: Niyati (2015), "Judicial activism for environment protection in India", *International Research Journal of Social Sciences,* www.isca.in/IJSS/Archive/v4/i4/2.ISCA-IRJSS-2014-327.pdf; PIB (2014); PIB (2014), *Environment Protection under Constitutional Framework of India*, http://pib.nic.in/newsite/PrintRelease.aspx?relid=105411; Rosencranz, Sahu and Raghuvanshi (2009), "Whither the National Environment Appellate Authority?", *Economic and Political Weekly*, www.jstor.org/stable/25663486.

India's cities are dominated by motorised two- and three-wheelers with two-stroke engines, which results in high local air pollution levels. Given the fact that much transport air pollution is local and varies from city to city, city-level initiatives have been playing an important role in spearheading air pollution action.[10] Many of India's most populous cities have been enforcing more stringent emissions standards than the nationwide minimum; the Delhi region had already adopted Bharat VI in 2018. In 2015 the NGT ordered a ban on petrol vehicles older than 15 years and diesel vehicles older than 10 years in the national capital region. It also banned the parking of 15-year-old vehicles in any public area. EPCA indicated that more restrictions on private vehicles could be imposed in Delhi in the instance that air quality reaches emergency levels.

India is rapidly progressing its policy measures aimed at modal shift (to rail) and alternative fuels, including biofuels and electricity (see Chapters 4 and 5 on energy efficiency and renewable energy). The GoI has stated ambitions to electrify its government-owned fleets and all two-wheelers. The National Mission on Electric Mobility of 2011 and the National Electric Mobility Mission Plan (NEMMP) 2020 of 2013 set in motion a range of initiatives to stimulate the deployment of these vehicles. As part of the NEMMP, the scheme "Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles" (FAME) was introduced by the Department of Heavy Industry. FAME reduces the upfront purchase price of hybrid and electric vehicles to stimulate early adoption and market creation. Phase I of the scheme ran until March 2019, recording more than 270 000 hybrid and electric vehicle (EV) sales promoted through the scheme. Phase II, from April 2019 with a planned duration of three years, expands the scope of the programme to other categories of vehicles (e.g. public electric buses).

In May 2017 NITI Aayog outlined a vision for the transformation of mobility in India, proposing actionable and specific solutions to accelerate India's leadership in advanced mobility. The Ministry of Power launched in 2018 the National E-Mobility Programme to be implemented by Energy Efficiency Services Limited (EESL), a joint venture of four national public-sector undertakings. Through these programmes, the GoI is focusing on creating charging infrastructure and a policy framework so that by 2030 more than 30% of vehicles in India are electric. While EESL's LED programme was a major success, the implementation of the public EV fleets has been challenging and the uptake is much below policy ambitious. India sold only 22 000 battery EVs in 2016, well short of the sales growth needed to meet the 6-7 million hybrid and electric vehicle sales target for 2020 (IEA, 2018e).

[10] For instance, Delhi has been spearheading conversion of passenger transport vehicles (including buses, taxis and three-wheelers) to compressed natural gas (CNG) and has been investing extensively in mass transport, including a metro rail system.

Power sector

The Environment Protection Amendment Rules (EPAR) introduced in December 2015 strengthened the SO_2 and NO_X emissions limits for new and existing plants. For existing and new coal-fired power plants they are, respectively, 200-600 µg/m^3 and 100 µg/m^3 of SO_2 and 300-600 µg/m^3 and 100 µg/m^3 of NO_X. These limits are comparable to or even more stringent than those in place in the European Union and the United States. Even though the coal types used in India are usually quite low in sulphur content, the new rules will require considerable retrofit investment in scrubbers and other control technologies. The limit for PM 2.5 from new power plants is 30 µg/m^3, while the limit for existing plants is 50 µg/m^3 or 100 µg/m^3 depending on when the plant was built. Given the location of power plants in highly densely populated areas, especially in the north of the country, implementation of the EPAR rules has an important role in the reduction of SO_2 and PM 2.5 emissions.

Air pollution limits in the power sector had not, however, been implemented by the initial deadline of 2017, two years after their adoption. Precise implementation status of the EPAR rules is evolving, with challenges due to ongoing litigation, policy uncertainty, delays in technology implementation and cost estimates by the thermal power industry in the course of 2018 and 2019. The compliance with the new standards was first postponed to 2022 by the GoI due to extensive retrofitting costs for the existing power plants. The Supreme Court, however, reimposed the deadline of 2021 for the most polluting plants and maintained the deferred deadline for the remaining plants at 2022. In August 2019 the Supreme Court additionally cancelled the further tightening of SO_2 and NO_X emission limits for thermal power plants by 2022 (proposed NO_X limit of 300 µg/m^3 by 2022 and 100 µg/m^3 limit thereafter), but maintained the implementation of the current air pollution standards (NO_X limit of 450 µg/m^3).

Industrial sector

Emission standards for key industrial sectors are also being gradually developed, though additional efforts are needed to ensure more comprehensive coverage. The cement and steel subsectors have standards for PM, NO_X and SO_2 emissions, while other subsectors (e.g. aluminium, large paper production facilities and small boilers) only have PM emission limits. SO_2 emissions are often tackled by the imposition of minimum stack height requirements and standards depending on the age or size of the installations. The stringency of the regulation of industry should, however, be strengthened to reflect technology capabilities. For instance, PM emission limits for most iron and steel processes (e.g. blast furnaces, sintering plants and basic oxygen furnaces) are set much higher than in other emerging economies[11].

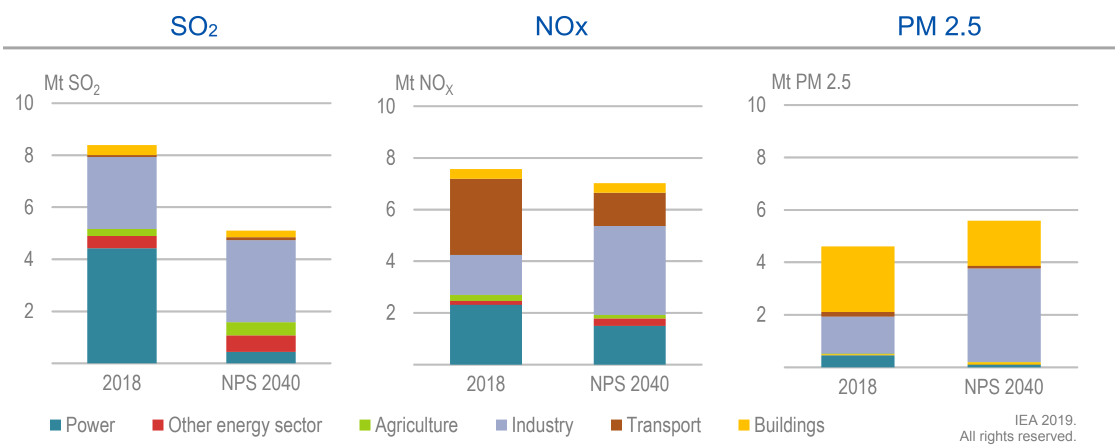
An important industry-related measure to improve urban air quality is also the focus on reduction of PM 2.5 pollution from brick kilns, which traditionally operate in densely populated areas. Other policy efforts, which are primarily aimed at addressing economic or climate change objectives, will also help curb pollutant emissions growth, notably efforts to increase industrial energy efficiency via the Perform, Achieve and Trade (PAT) scheme and its market-based trading programme for efficiency certificates.

[11] Three times higher in India than in China (150 µg/m^3 compared with 50 µg/m^3) and 7.5 times higher than in Germany (20 µg/m^3) (World Steel Association, 2014).

The outlook for air quality

India is expected to become the most populous country in the world by the mid-2020s, according to the United Nations, with an additional 315 million people expected to join the urban population by 2040 (and population density increasing to an average of 540 inhabitants per square kilometre [km^2]), with a corresponding increase in demand for additional housing, transport infrastructure and electricity, all of which drive air pollution. Policy action to curb the growth of air pollutant emissions is therefore essential. Successful implementation of the impressive policies already stated by the GoI will, according to IEA estimates, help to keep the growth in check (Figure 3.7). Without these policy measures, SO_2 and PM 2.5 emissions would roughly double by 2040 and NO_X emissions would grow almost 2.5 times. However, the decrease in pollution from sources covered by regulation (power and transport sectors) will be outstripped by the growth of pollution from industrial expansion, notably for PM 2.5.

Figure 3.7 Emissions of major air pollutants, 2018 and 2040 (NPS)



Note: STEP = Stated Policies Scenario, a projection based on existing policy frameworks and announced policy intentions.
Source: IEA (2019b), *World Energy Outlook 2019*.

In the power sector, the successful implementation of the EPAR regulations and diversification of the power mix is expected to lead to a reduction in total SO_2 emissions by 2040 relative to today, with the bulk of remaining SO_2 emissions shifting to industry. NO_X emissions drop slightly by 2040, as a strong decrease in emissions from coal plants is partially offset by increases from gas-fired plants and biomass combustion (Figure 3.7). Nevertheless, power generation in India more than triples over this period, with coal showing stronger absolute growth than any other source of power generation in India. As power plants are often located near cities, towns and villages, the potential impact on health of regulatory implementation is significant. Therefore, resolving the issues related to delay in and non-compliance with EPAR application offers considerable potential benefits.

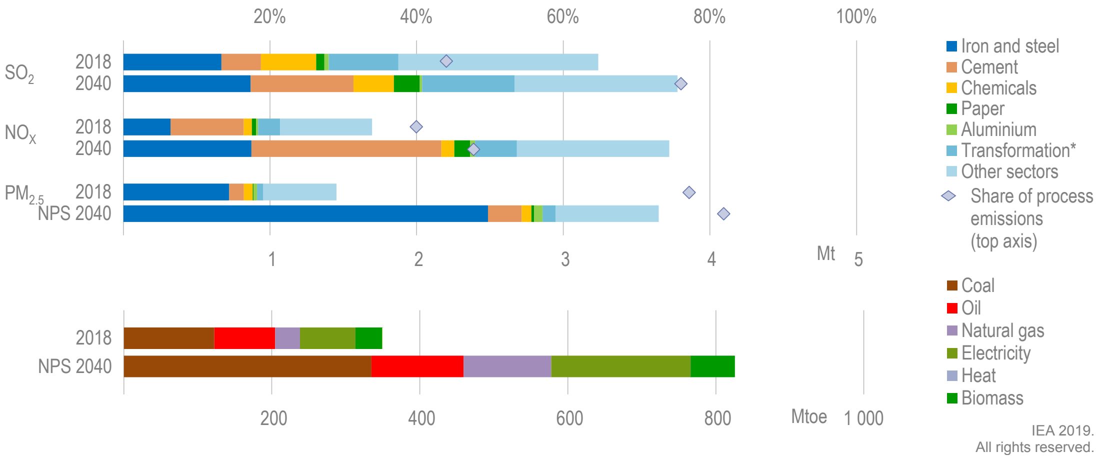
Implementation of EPAR requires the majority of the currently installed coal-fired capacity to be retrofitted with modern control technology and new-build plants to be equipped with advanced technologies for NO_X, SO_2 and PM control. Rapid expansion of modern renewables, including solar PV and wind power (underpinned by ambitious policy support), together with plans to expand nuclear capacity are crucial measures to move towards pollution-free power over time. In this regard, linking air quality with decarbonisation policy also plays an important role in addressing the two challenges in a synchronised manner.

In transport, the introduction of Bharat VI emissions standards for LDVs and HDVs is expected to play an important role in reducing emissions. Most importantly transport's share of NO_X emissions is expected to decline from 40% today to less than 20% in 2040. This is in spite of the exponential growth in car ownership and thanks to considerable fuel economy improvement. This decline is also underpinned by increasing stringency of standards for HDVs, with a key role for buses. But India will remain heavily reliant on road freight despite the intention to move part of this load to new dedicated rail freight corridors. Transport plays a relatively minor role (less than 5%) in India's energy-related emissions of PM 2.5. While vehicle standards play an effective role in reducing exhaust-related emissions, attention needs to be paid to non-exhaust emissions, such as from breaks and tyres, which are increasing considerably (also from EVs).

In industry, the implementation of tighter emissions standards is expected to improve the emissions intensity of key industrial sectors. Yet, air pollutant emissions from industry are expected to grow substantially over the coming decades to around two and a half times higher in 2040 than today. The growth in industrial output results in almost fourfold growth in coal consumption, with a large absolute increase in pollutant emissions. Despite policy efforts to improve emission intensities, regulation remains weak by international comparison and less stringent than in other sectors (for instance in transport). Three energy-intensive subsectors (steel, cement, chemicals and petrochemicals) give rise to the vast majority of emissions for each pollutant. The steel subsector alone gives rise to almost 50% of total PM 2.5 emissions from the industrial and transformation sector today. This share increases to almost 70% by 2040 as crude steel production increases by a factor of 4.5, compared with 2015 levels based on current and announced policies (Figure 3.8). Despite the low sulphur content of Indian coal, SO_2 emissions also increase dramatically, especially from the iron and steel subsector.

PM emitted by combustion activities in the buildings sector represents almost two-thirds of total energy-related PM emissions in India today, due to solid fuel cooking (the sector accounts for only a small share of total NO_X and SO_2 emissions). The way that this evolves in the projections is shaped by the major progress that India is expected to make in energy access. A key driver for reducing indoor air pollution is the reduction by almost a half the number of people without access to clean cooking facilities in rural areas (from around 840 million today to 480 million) and the switch from solid biomass and kerosene to LPG (and in some instances piped natural gas and electricity) by all urban households by 2040. These improvements cut PM 2.5 emissions from the buildings sector by over 30% in 2040, compared with today. This achievement, combined with reliable electricity supply, enables the phase-out of kerosene use for lighting, significantly reducing household fuel combustion and associated SO_2 emissions.

Figure 3.8 Industrial emissions of major air pollutants and fuel mix in industry, 2015 and 2040 (NPS)



* Transformation of fossil fuels (e.g. oil refining, oil and gas production, LNG terminals), excluding power and heat generation.

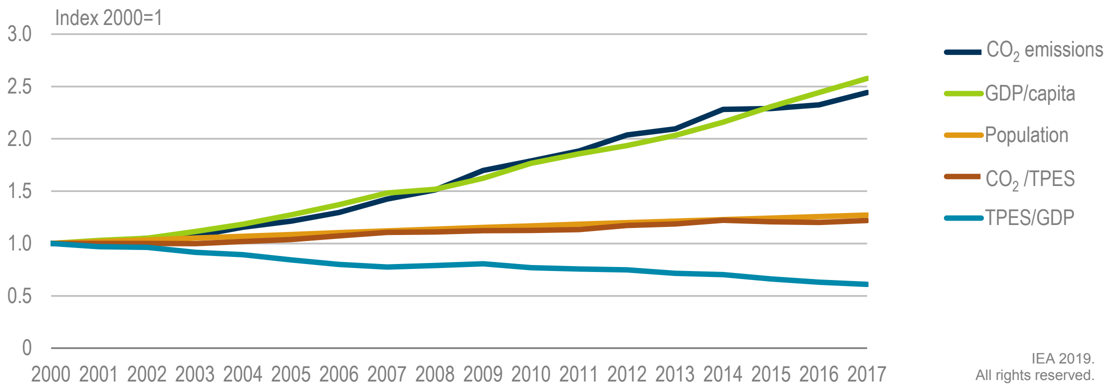
Note: The industry energy mix includes non-energy uses (mainly petrochemical feedstocks), as well as energy consumption by transformation industries, excluding heat and power generation.

Source: IEA (2019b), *World Energy Outlook 2019*.

Energy-related CO_2 emissions and carbon intensity: SDG 13

Energy-related CO_2 emissions in India nearly doubled in a decade, from 1 022 Mt in 2004 to 2 015 Mt in 2014, illustrating double-digit growth rates between 2005 and 2010 (Figure 3.9). They reached 2 162 Mt CO_2 in 2017. CO_2 emission are estimated to have grown again in 2017 and 2018, much in line with the global trend.

Figure 3.9 Energy-related CO_2 emissions and main drivers, 2000-17



Energy-related CO_2 emissions have more than doubled since 2000, driven by strong economic growth, increasing population and higher carbon intensity in the energy supply.

Notes: Real GDP in USD 2010 prices and purchasing power parity (PPP).

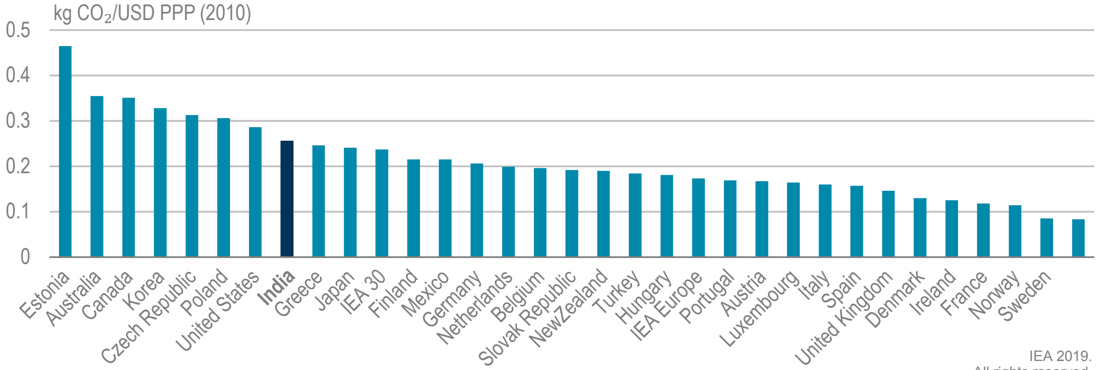
Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Estimates show that CO_2 emissions in India are likely to have reached 2 299 Mt in 2018, with year-on-year growth from 2017 of 4.8% (IEA, 2018f). Total energy-related CO_2 emissions increased by 144% from 2000 to 2017, close to the growth in GDP per capita.

Population and rapid economic growth have pushed up energy demand, which has become the key driver of India's rising CO_2 emissions and carbon intensity (Figure 3.9). From 2000 to 2016, the population grew by 27% and GDP per capita by 158%. The GoI objectives of increasing electricity access, combined with high economic growth rates (6.8% on average per year since 2010), and a growing population have led to an average increase in electricity demand of over 7% a year since 2010. Increased energy efficiency was not able to keep in check the increase in total energy demand, which almost doubled from 2000.

Over the period, CO_2 emissions intensity rose by 22%, but the emissions increase was less pronounced thanks to the improvements in energy intensity (TPES/GDP), which fell by 39%. The overall carbon intensity of India's economy puts India as the eighth highest in a comparison with IEA member countries (Figure 3.10).

Figure 3.10 CO_2 intensity of India and IEA member countries, 2017

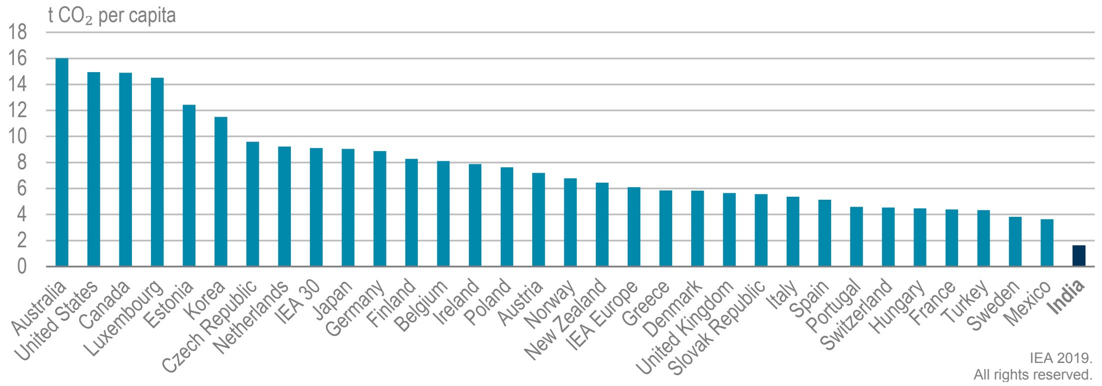


The high share of coal power makes India's economy relatively carbon-intensive.

Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

In spite of the high carbon intensity of the energy supply, India has a comparatively lower level of energy use per capita. India's per capita CO_2 emissions are therefore lower than any IEA member and Association country by a large margin, less than half of Mexico's and less than one tenth of Australia's (Figure 3.11). Sustaining economic development and delivery of societal objectives in India will require the adequacy of energy resources for expected growth in energy consumption and energy use per capita over coming decades. Ensuring energy consumption growth at the same time as reducing carbon intensity of supply will be the key challenge.

Figure 3.11 CO_2 emissions per capita in India and IEA member countries, 2017



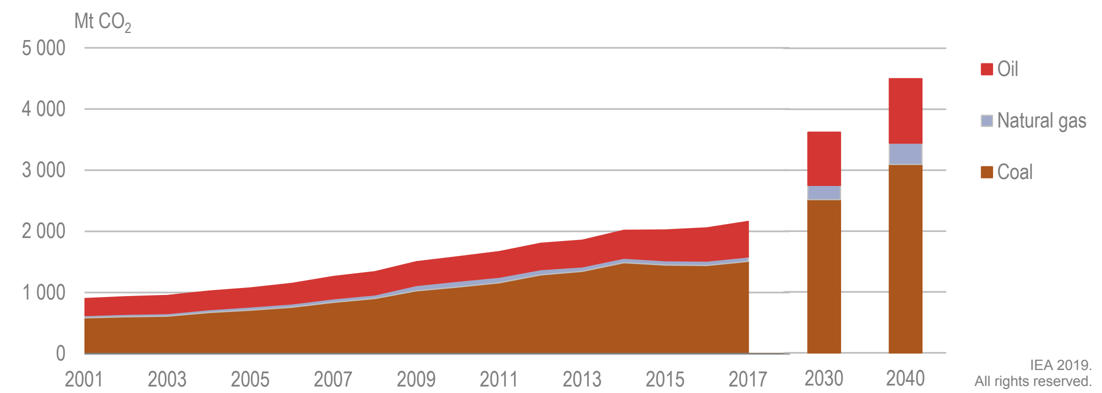
In per capita emissions, India ranks significantly lower than any IEA member country and a factor of 10 below Australia in the top.

Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Sectoral GHG status and stated policy outlook

Coal and oil dominate energy-related CO_2 emissions. Coal is the largest energy source in both power generation and industry, and its use accounted for 70% of total energy-related CO_2 emissions in 2017 (Figure 3.12). While coal-related emissions stabilised during 2014-16, their growth has resumed over the last two years, driven mainly by the power sector. Oil accounted for 27% of emissions in 2017, and the share is growing as oil consumption increases in both transport and industry.

Figure 3.12 Energy-related CO_2 emissions by source, historical and NPS projections for 2030 and 2040



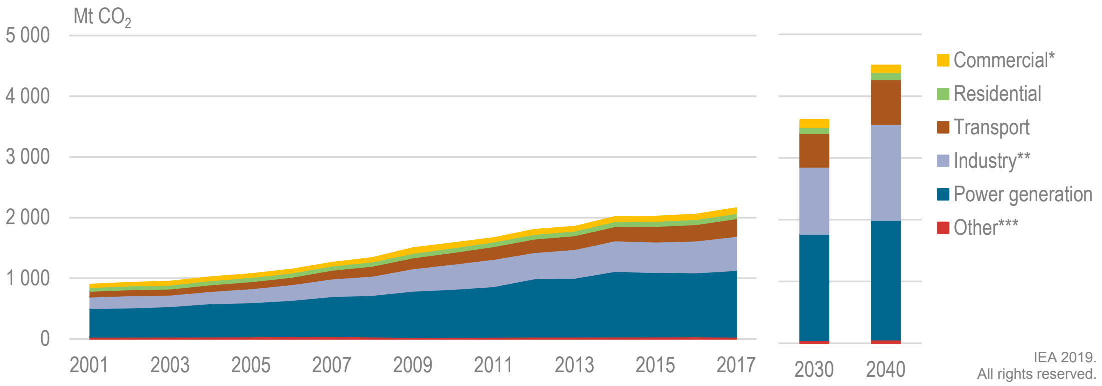
Coal-related emissions connected to the power sector have stabilised in recent years, while emissions from oil are increasing with the growth in transport and industry demand.

Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/; IEA (2019b), *World Energy Outlook 2019*.

The contribution of coal towards energy-related CO_2 emissions is expected to decline over time thanks to government policies to scale up low-carbon power generation. The outlook of stated policies shows the share of coal in power generation remaining at 70% in 2040. By that time, coal, oil and gas emissions are, however, together expected to have doubled due to the increase in overall energy demand. Nevertheless, the energy intensity of India's economy is projected to continue on a downward trajectory, with an almost 35%

improvement by 2030 compared to 2017 and 50% by 2040. The power sector represents just over half of total energy-related CO_2 emissions, with the industrial and transport sectors accounting for 13% and 26% of the emissions respectively (Figure 3.13).

Figure 3.13 Energy-related CO_2 emissions by sector, historical and NPS projections for 2030 and 2040

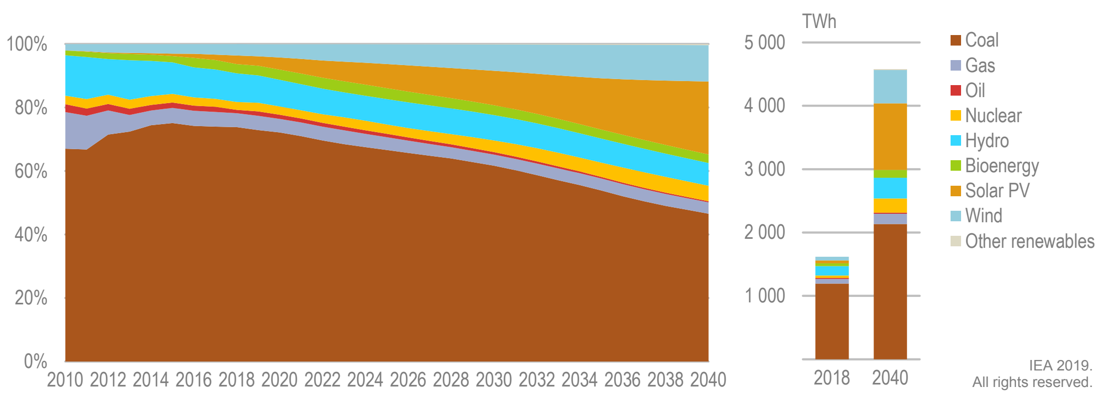


Power generation, heavily reliant on coal combustion, represents over half of total energy-related CO_2 emissions, its contribution having stabilised in recent years.

*Includes energy-related emissions in agriculture.
**Energy-related emissions from manufacturing and construction.
***Emissions from refineries and other energy industry, and non-defined emissions.
Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019,* www.iea.org/statistics/; IEA (2019b), *World Energy Outlook 2019*.

The power sector represents the largest emitting sector in India. The carbon intensity of India's power generation has declined by over 10% since 2010, thanks to more renewable energy sources and a step change in coal power efficiency (up 6% over the last five years) after a suite of new plants were installed. The dominance of coal power still gives India significantly higher carbon intensity than the more mixed power supplies of the People's Republic of China ("China") and the IEA average (see Chapter 7 on electricity, Figure 3.10), but India has witnessed a stronger downward trend recently.

Figure 3.14 Electricity generation by source in India, historical and projected (STEPS)



Coal remains the primary source of generation, but its share declines over time, reducing power sector emissions.

Source: IEA (2019b), *World Energy Outlook 2019*.

In the IEA projection based on current and announced policies, coal remains the primary source of electricity generation, but its share reduces from 74% today to 47% in 2030 and 48% in 2040 as renewables expand from the current 18% to 45% in 2040, resulting in 40% carbon-intensity reduction (Figure 3.14). Despite its falling share, the expansionary trend in coal power is the reason why power sector emissions increase by almost 80% by 2040 from 1.2 Gt CO_2 in 2017 to 2.1 Gt CO_2 in 2040. Further information regarding the power sector outlook can be found in the Chapter 7 on electricity.

While industrial CO_2 emissions contribute less than a quarter of the total, economic development in India, combined with several industrial initiatives, such as “Make in India”, lead to industrial emissions more than tripling by 2040 from 0.5 Gt CO_2 in 2017 to 1.6 Gt CO_2 in 2040. Primary subsectors contributing to this growth are those considered as “hard to abate”, with iron and steel continuing to account for around a third of emissions. Cement and chemicals, both accounting for about for around a tenth of emissions, are expected to grow significantly.

The transport sector represents a comparatively small part of GHG emissions in India, with its share expected to remain relatively stable. Nonetheless, overall it represents considerable growth from 0.3 Gt CO_2 in 2017 to over 0.7 Gt CO_2 in 2040. Road transport is almost solely responsible for growth in transport emissions, and this is expected to remain the case up to 2040.

Energy sector role in GHG mitigation policy

A National Action Plan on Climate Change (NAPCC) was adopted in 2008 with the aim of driving measures that promote India’s developmental objectives while addressing climate change as a co-benefit. This objective was to be implemented through eight national missions covering both mitigation as well as adaptation efforts, with the energy sector being instrumental in delivering upon their objectives. The eight missions are:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change.

Missions that directly relate to the energy sector include: solar; enhanced energy efficiency; and sustainable habitat, which includes a sub-focus on buildings codes and energy conservation, urban transport planning, and waste management. However, the energy sector also has potential impacts on some of the less directly related missions, such as water. In 2015 four more missions were added, including for wind and waste-to-energy. States were instructed to elaborate their own Climate Change Plans, most of which have been completed.

India is the third-largest national emitter of GHGs (after China and the United States), and with rapidly rising emissions, India also plays a key role in the international dialogue on climate change as a major developing country. In 2009 at the Conference of the Parties (COP) 15 in Copenhagen, India announced voluntary targets to reduce the emissions intensity of its GDP by 20-25% against 2005 levels by 2020. Then, in 2015 the GoI built on this target in its submitted Intended Nationally Determined Contribution (INDC), which became India's first NDC after the GoI ratified the Paris Agreement in 2016. India's NDC includes the following new energy sector-related targets:

- To reduce the emissions intensity of its GDP by 33-35% from 2005 levels by 2030.
- To increase the share of non-fossil fuel-based energy resources to 40% of installed electric power capacity by 2030,[12] conditional on technology transfer and international climate finance support, such as the Green Climate Fund (GCF).
- To create an additional (cumulative) carbon sink of 2.5-3 $GtCO_2$-eq through additional afforestation by 2030.

At the UN Climate Week in New York, on 23 September 2019 Prime Minister Modi announced that India's electricity mix should reach 450 GW of renewable energy capacity, which is more than the entire power plant fleet of India in 2019.

India's NDC also prioritises efforts to adapt to climate change impacts (see section on climate change adaptation below). Additionally it provides a broad indication of the amount of climate finance support needed to reach the NDC's goals to 2030, estimating some USD 213 billion for adaptation measures (USD 7.7 billion of which is for the energy sector alone) and around USD 834 billion for mitigation measures. The GoI is on track in implementing its NDC, through the policy drivers designed to implement the National Mission Programmes. The GoI estimates that implementing national climate plans would cost more than USD 2.5 trillion cumulatively between 2015 and 2030.[13]

India's NDC also describes at length an impressive array of policies and plans related to climate change already underway in India. The key policies relevant for meeting the NDC goals of the energy sector relate to India's NAPCC missions. While many of these policy drivers are instrumental to the NDC, they are also directly related to other areas of sustainable development as they are also crucial to addressing air quality, energy access and efficiency, or to enhancing renewables. Thus the key national missions will not only address climate change, but also deliver other objectives, highlighting the cross-cutting importance of climate action across the sustainable development goals.

According to several analyses, current trends point to India being able to meet its NDC targets.[14] According to IEA estimates, the CO_2 intensity target will likely be met or perhaps even surpassed by current and announced policies. Current and announced policies are estimated to reduce the emission intensity of India's GDP by up to 43% from 2005 levels

[12] To attain this goal, some 200–340 GW of non-fossil fuel energy capacity would need to be installed by 2030, including a range of renewable energy technologies. This ambitious target could be within reach as it builds on the goal set by the Ministry of New and Renewable Energy of installing 175 GW of renewable energy capacity by 2022, of which 100 GW is solar power (Jawaharlal Nehru National Solar Mission).

[13] http://pib.nic.in/newsite/PrintRelease.aspx?relid=128403.

[14] See, for instance: https://www.wri.org/sites/default/files/pathways-meeting-indias-climate-goals.pdf and https://climateactiontracker.org/countries/india.

by 2030. Equally, the target to achieve 40% of non-fossil fuel-based energy resources is well under way, with plans to add extensive variable renewable capacity to current renewable capacity that primarily consists of hydropower. The GoI recently announced target to increase its renewable energy capacity to 450 GW after previously committing to achieving 175 GW by 2022. This target means a fivefold increase in current renewable capacity and is also more than India's currently installed electricity generation capacity. Delivering upon stated clean energy transition objectives and energy demand growth requirements in India will require increasing the annual level of investment in the energy sector by approximately 25% from 2018 levels on average during 2019-25 and by almost 50% on average during 2025-40.

Pricing of energy sector externalities

India has a range of energy sector-related carbon pricing initiatives, which are either implemented or at conception stage. The nationwide Clean Energy Tax on coal (or coal cess) was adopted in 2010, being levied on coal production and imports. The tax was initially set at INR 50 (USD 0.72) per tonne of domestic and imported coal, was quadrupled to INR 200 (USD 2.88) per tonne of coal in 2015 and doubled again to INR 400 (USD 5.75) per tonne in 2016.

The revenue was initially allocated to the National Clean Energy and Environment Fund (NCEEF) to invest in clean energy projects and technologies. A total of USD 4.2 billion were accrued in the NCEEF until it was subsumed under the Goods and Services Tax (GST) reform, which aims to bring several direct and indirect taxes under the federal GST. Coal production and imports remain subject to a coal compensation cess of about USD 6 per tonne of coal. The precise allocation of revenue from this cess is not earmarked. However, the Ministry of Finance expressed confidence that financing of clean energy and environment projects should not suffer from the GST reform.

Several other carbon pricing schemes are in scoping or pilot stages. For instance, the MoEFCC is contemplating two pilot carbon markets for micro, small and medium-sized enterprises (MSMEs) and also for the waste sector, in association with the World Bank's Partnership for Market Readiness programme as outlined in India's Market Readiness Proposal. MSMEs represent one of the sectors that has been identified with significant GHG mitigation potential, as they are a major energy consumer (22.5 Mtoe/year).[15] Despite a few initiatives and policy efforts to reduce the carbon intensity of the sector, the lack of data on the distribution of energy consumption within the MSME sector is a major barrier to implementation. A possible pilot carbon market in the sector is being discussed, including the formulation of appropriate policies, development of interim linkages, establishment of baselines and simplified monitoring, review, and verification systems. MSMEs also typically do not have the resources to engage in trading and establishing a registry for the large number of MSMEs would be challenging.

The waste sector is another potential candidate for a market-based mechanism. If not treated properly, increased waste generation leads to an increase in GHG emissions, due to methane and nitrous oxide formation. According to the Nationally Appropriate Mitigation Action (NAMA) for the waste sector, the sector's emissions are expected to more than double between 2015 and 2030, from 19 Mt CO_2-eq to 41 Mt CO_2-eq.[16] A market-based

[15] www.thepmr.org/system/files/documents/India%20MRP%20Final%2027%20Feb%202017.pdf.
[16] www.thepmr.org/system/files/documents/India%20MRP%20Final%2027%20Feb%202017.pdf.

mechanism in the waste sector could help phase out methane emissions from solid waste disposal. Moreover, it could also help the sector move from representing a cost to a for-profit business through the monetisation of GHG emission reduction benefits by, for instance, selling compost, electricity and refuse-derived fuel.

Energy sector climate change adaption and resilience

India is a country particularly vulnerable to climate change. Energy should play an important role in addressing climate change adaptation challenges. The sector will need to become more resilient to ensure security of supply during extreme climatic impacts such as heat waves, floods, droughts and a rise in overall temperatures. The sector can also contribute to mitigating the impact that climate change will have on the country.

According to the ND-GAIN (University of Notre Dame Global Adaptation Initiative) adaptation score, India is the 51st most vulnerable country and the 71st least ready to adapt.[17] The country has a great need for investment and innovation to improve its readiness to adapt to climate change, and a great urgency for action. The adverse impacts of climate change are amplified by the widespread poverty and the dependence of India's population on climate-sensitive sectors. Adaptation and resilience are key priorities for the GoI. India's NDC highlights current adaptation initiatives and the plans under development in each Indian state. Climate vulnerability varies significantly from state to state, depending on the topography, climatic conditions, ecosystems and diversity in social structures and economic conditions.

The issue of climate change vulnerability has been raised to the highest political attention with the establishment of the Prime Minister's Council on Climate Change (PMCCC) in 2008. PMCCC ensures a co-ordinated response to climate change issues, overseeing the formulation of action plans not only for mitigation, but also for adaptation and monitoring key policy decisions. Of the eight national missions in the NAPCC, five have a focus on adaptation. These are in key sectors, such as agriculture, water, Himalayan ecosystems, forestry, capacity building and knowledge management. The NAPCC is intended to be supplemented by sub-national actions at the state government level. Currently around 2.8% of India's GDP is dedicated to programmes with critical adaptation components.[18] Enhanced investment in adaptation activities will require additional domestic and international financial support. In its NDC, India estimates that USD 206 billion will be needed to implement these adaptation measures over the period 2015-30. A National Adaptation Fund has been set up with an initial allocation of INR 3 500 million (around USD 50 million) to support the activities carried out by each state and ministry.

The water-food-energy nexus is particularly relevant for the energy sector in India. Water is essential for energy production and constraints on water can challenge the reliability of existing operations as well as the physical, economic and environmental viability of future projects. India is already classified as "water stressed" and between 2013 and 2016, 14 of India's 20-largest thermal power stations were on occasion forced to shut down operations due to water shortages (Luo et al., 2018). As such it is particularly important to assess existing and potential future water needs when planning energy sector investment in order to avoid potential choke points and identify positive synergies. India's groundwater

[17] https://gain.nd.edu/our-work/country-index/.

[18] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf.

consumption in agriculture has increased strongly, as other sources of water are scarce and electricity for pumping is unmetered and highly subsidised. India extracts a quarter of the world's groundwater annually, more than China and the United States combined. Besides making available alternative water sources, electricity subsidy reform can help reduce groundwater use.

In 2016 India's total energy-related water withdrawals[19] were around 35 billion cubic metres (bcm), while energy-related water consumption[20] was roughly 5 bcm. The IEA *World Energy Outlook* projects India's total energy-related water withdrawals to almost double in the NPS by 2040, while energy-related water consumption increases almost fivefold. The increases reflect a growing role for nuclear as well as a continued, though diminished, reliance on coal-fired power plants, many of which are located in areas of water stress. IEA analysis of water availability constraints for India's coal-fired power generation show that water stress could have an increasingly material impact on the choice and deployment of cooling technologies and the location of new coal-fired power plants. By 2040 more coal-fired power plants are expected to utilise wet tower and dry cooling, with more plants built in close proximity to coal mines, which are predominately located in areas not expected to experience water stress. As a result, generation costs are projected to increase due to costs related to fuel transport, cooling systems and network expansion (IEA, 2015).

While India has announced ambitious renewable energy targets, this IEA analysis still provides an illustrative message about the potential impact of water availability on energy choices in the future. Moreover, it is important to note that low-carbon technologies are not immune to potential disruption from water scarcity either. In fact, while a lower-carbon pathway offers significant environmental benefits, the suite of technologies and fuels used to achieve this pathway could, if not properly managed, exacerbate water stress or be limited by it. Some technologies, such as wind and solar PV require very little water. However, the more a decarbonisation pathway relies on biofuels production, the deployment of concentrating solar power, carbon capture or nuclear power, the more water it consumes, making it important to incorporate water into any energy policy decision.

Hydropower, which currently accounts for 9% of India's power generation, is particularly vulnerable to changes in water availability (both temporally and seasonally). There is significant uncertainty regarding the precise magnitude and location of the impacts of climate change and what changes in rainfall patterns might occur as a result. One possible outcome is more frequent and intense droughts and floods, changing the patterns of water flow over the year, straining reservoir management and altering the viability of hydropower. A recent study which analysed the seven-largest hydropower projects in India (Nathpa Jhakri, Bhakra Nangal, Srisailam, Nagarjuna Sagar, Hirakud, Sardar Sarovar and Indira Sagar) found that the temperature and level of precipitation are projected to increase (Ali et al., 2018). As a result, the study projected that hydropower electricity production would rise by the end of the century. However, given the uncertainty and continued importance of hydropower for India's electricity mix, this topic would benefit from further

[19] The volume of water removed from a source.

[20] The volume of water withdrawn but not returned to a source.

assessment to help policy makers better integrate climate resilience into the planning of future hydropower operation and construction.[21]

Recognising the existing and future threat of water shortages to its energy sector, India has put in place a range of energy sector-related water policies and regulations. India updated and implemented a ruling in the summer of 2018 requiring new and existing thermal power plants to switch to cooling towers and put in place water consumption limits per MWh. In addition, India has put in place rules limiting shale gas exploration and the availability of water to clean solar panels. The implementation of waste regulation will be increasingly important given India's ambitious plans for waste-to-energy.

Developing energy sector climate adaptation and resilience measures should be done hand in hand with energy mitigation policies to prevent negative consequences of climate change to the maximum extent possible.

Assessment

The GoI has placed sustainable development at the heart of its policy action, notably the goals of reaching universal energy access, clean cooking, improving air quality and tackling climate change.

While universal electricity access is within reach, IEA analysis shows that under current trends more than half a billion Indians will still lack access to clean cooking by 2030, with implications for health and lost opportunities for women. IEA analysis of air pollution policies shows that policies announced and implemented by the GoI will lead to considerable reduction in pollutant emissions in certain sectors. This includes SO_2 emissions reduction in the power sector and reductions in NO_X from transport. However, outdoor air pollution is likely to remain a significant health burden due to rise in air pollution from new sources, notably transport and industry.

Within the climate change space, the policy missions show how India's energy sector transition is gathering speed at impressive pace.

With its commitment under the Paris Agreement (NDC), India is working towards feasible results by 2030 and is on track to achieve its objectives. Current trends indicate strong progress in the capacity additions from non-fossil fuels and a 20% decline in emission and energy intensity over the past decade. In fact, the prime minister announced in September 2019 at the UN Climate Summit an increased ambition to attain 450 GW of renewables capacity (without providing an exact time frame). The two main energy-related objectives in India's NDC – to reduce CO_2 emissions intensity by 33-35% from 2005 levels and to achieve 40% non-fossil fuel electric power capacity, both by 2030 – are likely to be achieved and even surpassed based on announced policies. In spite of this, total energy-related CO_2 emissions are set to continue to rise under current trends, as economic development continues apace. Therefore, the IEA encourages the GoI to seek additional policy measures that could be taken in the domains of energy access, air quality and climate change.

[21] The IEA is working on estimating the escalating variability and uncertainty in hydropower generation due to climate change impacts to reconsider system reliability. The initial work has focused on hydropower in Africa, with results published in IEA *World Energy Outlook 2019*, but work on other regions is to follow.

Energy access

India's significant acceleration of energy access through a strong policy push by the GoI is commended. A majority of people who have gained electricity access in India since 2000 have done so as a result of grid extension, with coal powering almost three-quarters of the new electricity supplied. Enhancing the use of clean energy and ensuring 24/7 supply should now follow suit to ensure that other sustainable development objectives can also be met. While the policy challenge to achieve clean cooking is quite different, some of the lessons learned from the success of an enhanced policy push for electrification could help the GoI in devising policy to tackle access to clean cooking facilities and reduce the number of people still relying on biomass for cooking.

Energy sector and air quality

The GoI has developed air quality regulation for power, transport and industry alongside codes and regulations in the buildings sector. While the government is commended for its air pollution regulatory framework, implementation remains challenging, in some cases leading to delays and gaps in enforcement. Moreover, while implementation of air quality policies is expected to mitigate the growth in air pollutants, total volumes of air pollution are expected to stay close to today's level by 2040, even with currently announced plans and assuming effective enforcement. Additional policy levers should be explored to address growth from specific sectors.

Firstly, it is clear that the Pollution Boards require more funding, staffing and capacity building, as well as enhancement of the incisiveness of their inspection powers. For instance, the standards set by EPAR are stringent and achievable, but they require closely monitored compliance at the plant level with penalties for non-compliance. Implementation efforts need to be better co-ordinated; for example, preventive measures under the Graded Response Action Plan of 2017 have seen a lack of implementation due to difficulties in joining up and mobilising numerous actors and authorities to implement measures in multi-jurisdictional sectors, such as cities.

Secondly, regulation is sometimes adopted without sufficient consultation with stakeholders and may therefore – temporarily – fail. The challenges associated with the implementation under EPAR of retrofitting coal power plants with desulphurisation offer important lessons. The regulation implementation deadline was initially set for 2017, but has been postponed until 2022, with ongoing court cases set to push back the implementation date, as it is unclear if and how the costs of the retrofits will be handled by the companies and if they could be socialised through the tariffs approved by the State Regulatory Commissions. The Supreme Court brought the deadline forward to 2021 for power plants in heavily polluted areas, with additional ongoing court cases in relation to the regulations on air pollution limits in the power sector.

These new deadlines are still considered to be ambitious and it is expected that, instead of retrofitting, some of the older high-polluting plants will be phased out at the end of their economic life.[22] For those that will be retrofitted, the associated costs could represent a substantial economic challenge in the increasingly competitive electricity market of India, especially for those plants with a limited remaining lifespan. While the cumulative

[22] The total annual cost of a flue-gas desulphurisation (FGD) unit in India is estimated, on average, at USD 23.5 million and the average cost per tonne of SO_2 removed at USD 613/tonne. Source: Cropper et al. (2017)

investments required to introduce control technology are large,[23] the value of the social and public health benefits obtained from improved air quality is arguably much greater. The solution lies in finding ways to enable the generators investing in control technology to recoup the additional costs. Considering their already stressed finances and their problems in sourcing water and fuel supply, it is becoming increasingly difficult for these power companies to recoup the costs of these environmental upgrades (Jain, 2018). If not controlled by the government, this could eventually lead to an increase in power tariffs. As explained in Chapter 9 on coal, a policy mix relying on both carrots and sticks would be most desirable (with financial incentives, transition time and strong regulatory constraints).

An additional example is the regulation that mandates washing of coal with an ash content of more than 34% and which is transported over more than 500 kilometres, which appears to be poorly enforced. While norms might sometimes be championing the right ambition, their implementation is often inadequately designed. Still, some polluters do incur hefty fines, often based on complaints filed with the green courts and sanctioned by judiciary court judgements.

Thirdly, it will be important for the GoI to assess its policy levers with regard to future air pollution objectives. The IEA outlook shows that implementation of current air pollution regulations will tackle existing sources of air pollution. If implemented effectively, the power sector regulations could make significant inroads. Despite this, our outlook for air pollution shows that the total level of emissions will remain roughly the same as today through to 2040, due to sheer growth in air pollution from industry, which is not currently targeted. Across the transport and buildings sectors, the level of air pollutants is set to remain elevated in spite of the fact that we see an improvement in total NO_X and PM 2.5 emissions. Due to the considerable growth in industrial output and associated threefold increase in use of coal in industry to meet additional energy demand,[24] air pollutant emissions from industry are expected to grow substantially – by around two and a half times today's levels by 2040. By 2040 industry contributes about 60% of total SO_2 and PM 2.5 emissions and 50% of total NO_X emissions. The dramatic increase in industrial growth and associated additional air pollution calls for stronger regulation of the sector's emissions. Regulations can significantly reduce air pollution if incentivised by both stringent financial and regulatory frameworks (setting emissions limits and cost recovery) and monitoring and enforcement (IEA, 2016).

Energy and climate adaptation and resilience

Energy sector solutions will play an important role in addressing climate change adaptation and resilience challenges. India is commended for having implemented a range of energy sector-related water policies and regulations, in the context of shale gas and cleaning solar panels, as well as for cooling in thermal power and nuclear plants. Given the potential vulnerability to climate change, the GoI should further explore energy sector climate adaptation and resilience measures. Water constraints will have an impact on development of both renewable energy and coal power. The choice of cooling technologies and the location of new coal-fired power plants should be determined with water stress

[23] Estimates vary: The total cost for the industry to comply with this regulation was estimated to be around USD 39 billion (according to the Times of India), while other source quotes at around USD 145 billion.

[24] The composition of fuel use in industry remains relatively stable; electricity meets about 20% of demand now and in 2040 and coal grows from 43% share today to 53% share in 2040. All fuels, however, grow exponentially.

considerations in mind. Hydropower sensitivity to temporal and seasonal changes in water availability should also be assessed for energy security reasons. Finally, planning for any deployment of concentrating solar power, carbon capture or nuclear power should be carried out in accordance with water policy objectives.

Energy sector cost-effective response to climate change

India has an extensive set of policy measures to reduce its emissions, organised primarily around the eight key NAPCC missions, which are being continuously updated and complemented with additional measures. IEA analysis indicates that India's NDC will be largely met, or perhaps even surpassed, with the current framework of policy measures. Closer integration of policy measures can, however, deliver efficiency gains and reduce costs through better policy sequencing and institutional co-operation.

A comprehensive policy mix is needed to address different types of challenges within the climate change areas. IEA analysis shows that these can be allocated to three principal areas: negative-cost opportunities; medium-cost near-term measures; and longer-term measures.[25] The GoI has effectively introduced policy measures for all three domains of low-carbon transition policies.

First, to ensure effective NDC implementation, an integrated approach is needed both across policy objectives and across the levels of government. NDC responsibilities primarily lie with the central government (with the MoEFCC at the helm). While the states (most of which have climate plans) do not have any formal responsibility to implement climate goals, they play a key role in ensuring that the NDC is implemented. Co-ordination of NDC implementation across departments in the central government could be enhanced to prevent policies being implemented in silos and at suboptimal level. Equally, while there is no formal devolution of the NDC to state level, implementation of state climate plans will be important. States offer different mitigation potential (e.g. with respect to high reliance on coal mining or endowment with renewable sources). Capacity building on data development at state level or integrated state-level modelling to understand the apportionment of targets to states are therefore important.

Secondly, areas of development and improvement also exist for different policy areas. Carbon pricing plays an important role in the decarbonisation policy frameworks of many emerging economies. The GoI already introduced a nationwide Clean Energy Tax on coal. Carbon pricing could be explored further as an effective policy tool to drive deployment of lower-carbon alternatives in large emissions-intensive industries as well as in the power sector, given that they are not only the drivers of future high energy-related CO_2 emissions, but also air pollution.

Mainly focusing on energy efficiency, the PAT scheme covers a majority of large installations and has created a registry and trading platform, which lends itself to a possible

[25] Negative-cost (i.e. money-saving) opportunities, such as energy efficiency, can be unlocked through complementary energy efficiency interventions to reduce market barriers and aid consumer decisions, with correct energy pricing (via subsidy reform and carbon pricing) also playing an important supporting role. Opportunities based on cost optimisation (for example, dispatch of electricity generation, or private investment decisions in energy infrastructure, industrial plant processes and efficiency improvements) rely on visible price signals such as a carbon price. Finally, extending the scope of long-term emissions reduction opportunities is achievable through investment in technology RD&D (to bring down the costs and improve the performance of advanced technologies) or policy support for underpinning infrastructure (such as smart grids or EV charging infrastructure).

extension to carbon trading, thereby bringing carbon pricing up the policy-making value chain. In particular, revising and expanding the PAT scheme for the power sector (and potentially other sectors of interest) could provide appropriate price signals. The power sector could arguably be effectively carved out of the PAT scheme and migrated to a carbon scheme, using the PAT registry and trading platform. Many jurisdictions have introduced carbon pricing in a prudent way, with pilots for selected sectors or provinces and parameters set in a way to gradually increase the price of carbon. The GoI could use a similarly prudent approach for the power sector, which would help phase out inefficient coal and also benefit renewables and gas-powered generation. Carbon pricing can also serve as a tool to ensure effective energy pricing for industry and households. Cost-covering energy prices for residential and industrial users can play an important role in India's clean energy transition. Energy pricing reforms and carbon pricing can go hand in hand to address environmental externalities and provide appropriate price signals for end-use consumption.

Recommendations

The Government of India should:

- Strengthen enforcement of environmental rules, notably on air pollution, by galvanising the authorities to trigger preventive measures at, inspect, launch procedures against, fine and close polluters. Support the adequate financing of Central and State Pollution Control Boards, notably for tighter-meshed pollution monitoring systems.
- Target as yet unregulated sectors with comprehensive and stringent air pollution regulations, notably in industry, transport and buildings.
- Use the PAT platform (rather than creating new schemes) for those industries as a pilot for CO_2 emissions trading.
- Enhance integration of policy responses to air quality, energy access and GHG emission reductions to fully harvest their co-benefits. Boost policy co-ordination across different level of government to foster the implementation of India's NDC.

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4. Energy efficiency

Key IEA data

(2017*)

Energy TFC: 591.2 Mtoe (oil 33.1%, bioenergy and waste 26.6%, coal 17.1%, electricity 16.9%, natural gas 6.1%, solar 0.1%); up 50.2% since 2007

Energy TFC by sector: industry 42.4%, residential 29.4%, transport 16.6%, services 11.5% (includes commercial and public services, agriculture, forestry and non-specified)

Energy TFC per capita: 0.44 toe (IEA average 2.9 toe)

Energy intensity (TFC/GDP): 70 toe/USD million PPP (IEA average: 74), -24% since 2007

* India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. So, the statement: "In 2017 total final consumption was 591.2 Mtoe" refers to the data India has collected (and supplied to the IEA) from April 2017 to March 2018.

Overview

India's energy demand has increased at a rapid rate. The expected economic and population growth, together with urbanisation and industrialisation, point towards continued growth in energy demand.

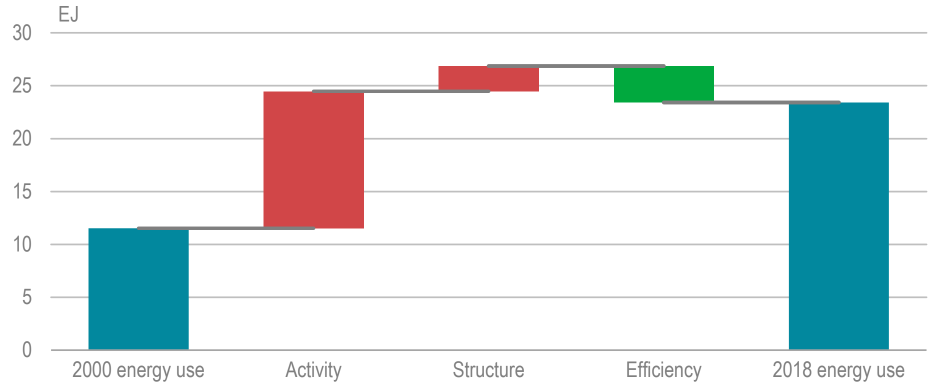
India has made significant progress on improving energy efficiency. Efficiency gains since 2000 resulted in the avoidance of 15% more energy use in 2018, with the industrial and service sectors providing the largest source of savings. However, these efficiency gains have been greatly overwhelmed by the impact of activity linked to increased economic growth, improved living standards and demand for energy services, which more than doubled India's energy use between 2000 and 2018 (Figure 4.1). As a result of efficiency measures implemented since 2000, in 2018 India avoided:

- 15% more energy use.
- 300 million tonnes or 14% more carbon dioxide (CO_2) emissions.
- 8% more oil imports.
- 12% more gas imports (IEA, 2019a).

As India continues to grow rapidly, there are significant opportunities to further increase the ambition of the country's energy efficiency policies and programmes. Energy efficiency can also play a key role not only in fostering economic efficiency and competitiveness, but also in achieving India's objectives to limit greenhouse gas (GHG) emissions growth and to reduce indoor and outdoor air pollution under the country's Nationally Determined Contribution (NDC).

With current policies in place, the IEA expects India's energy demand to more than double to 2040, while electricity demand could triple with current policies in place (IEA, 2018a). This will require significant investment in capacity addition and grid infrastructure and energy efficiency will be an important consideration to avoid stranded assets and underutilisation.

Figure 4.1 Composition of energy demand, 2000 and 2018



Energy efficiency has avoided an additional 15% of energy demand in India since 2000.

Note: EJ = exajoule.

Source: IEA (2019), Energy Efficiency 2019.

In the medium term, the Central Electricity Authority (CEA) expects India's electricity requirement (demand plus transmission and distribution losses) to reach 1 566 TWh (peak demand 225 751 MW) by 2021-22 and increase to more than 2 047 TWh in 2026-27 (peak demand 298 774 MW). This requires investment in capacity additions of more than USD 304 billion (CEA, 2018). Energy efficiency costs less than the cost of meeting electricity demand with new power plants. This is before taking into account the significant environmental and socio-economic benefits that energy efficiency also brings. Analysis of energy efficiency programmes shows that the average total cost per lifetime kilowatt hour (kWh) saved is typically less than USD 0.03 (IEA, 2017a). For example, the cost of generating one kWh of electricity in India from a thermal power plant of 500 MW capacity comprising of 2X250 MW units amounted to INR 4.91 or USD 0.068 in 2018.

Looking ahead, if India were to increase the ambition of its energy efficiency policies to promote the deployment of cost-effective energy efficiency measures, then the country could by 2040:

- Save USD 189 billion per year in energy imports, which stems primarily from a reduction in annual coal imports of 70 Mt, annual gas imports of 13 bcm and oil imports of 1 million barrels per day.[1]

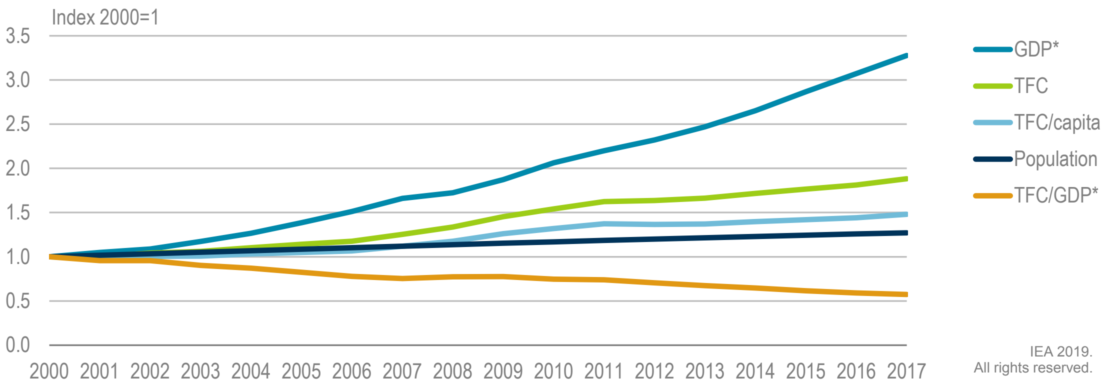
[1] As projected under the IEA Efficient World Scenario compared to the IEA New Policies Scenario in the IEA *World Energy Outlook* 2018.

- Avoid the generation of 875 TWh of electricity per year, which would avoid generation investment of USD18 billion per year and annual fuel consumption of 175 Mtoe (IEA, 2016).[2]

Supply and demand trends

In 2017 India's total final consumption (TFC) of energy was 591 Mtoe, an increase of 88% from 2000 and 50% from 2007 (Figure 4.2). Between 2000 and 2017, gross domestic product (GDP) with purchasing power parity (PPP) increased by over 200% and the population grew by 27%. The structure of the economy is changing and growth in less energy-intensive sectors, such as information technology and other services, contributes to improved energy productivity. From 2000 to 2017 India's TFC per unit of GDP fell by 43%, compared with 25% for the world on average and 24% for IEA member countries. Meanwhile, energy supply per capita grew by nearly than 50%. Electricity demand is increasing rapidly in India, although, at 910 kWh, per capita consumption is less than a third of the global average (IEA, 2018b).

Figure 4.2 Energy TFC and drivers, 2000-17



India's TFC has nearly doubled since 2000, driven by strong growth in GDP and population.

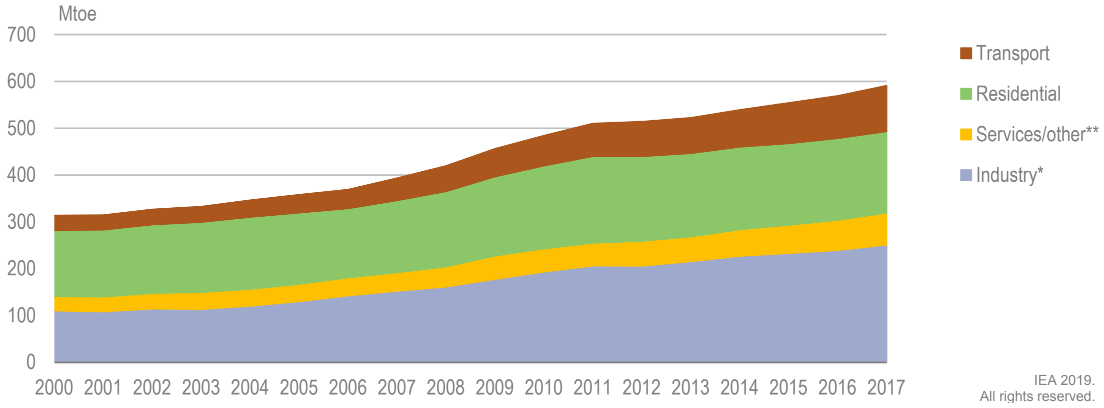
*GDP data are in billion USD 2010 (PPP).
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Energy consumption by sector

The industrial sector has been the largest energy consumer in India since 2008, and accounted for the largest share of growth (Figure 4.3). The residential sector was the second-largest consumer. While the share of energy demand for transport and commercial (including non-residential buildings, public services, agriculture, forestry and fishing) is relatively low, it is nonetheless increasing.

[2] As projected for the IEA India Efficiency Scenario as compared to the IEA New Policies Scenario in IEA World Energy Outlook 2016, India Energy Efficiency Outlook.

Figure 4.3 Energy TFC by sector, 2000-17



Industry accounts for 42% of TFC and has experienced significant growth in the past decade.

*Includes non-energy use.

**Includes commercial and public services, agriculture, forestry and fishing.

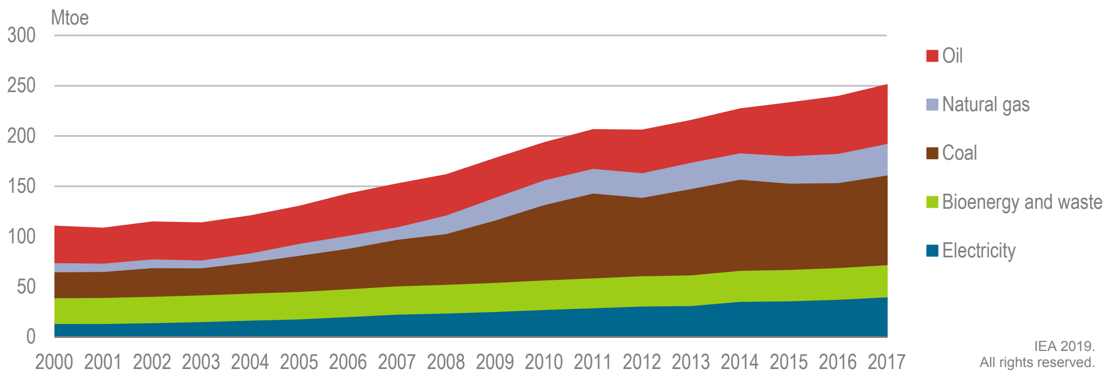
Note: The slowdown in energy demand in the residential sector reflects reductions in the use of traditional biofuels and a shift towards more efficient cooking.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Industry

India's industrial sector, including non-energy consumption in process industries and construction, accounted for 42% of TFC in 2017. Industrial energy demand is growing rapidly and consumption has increased by 128% since 2000 (Figure 4.4).

Figure 4.4 Energy TFC in industry by source, 2000-17



Energy consumption in the industrial sector has more than doubled since 2000, with the largest share supplied by coal and oil.

Notes: Includes non-energy consumption; bioenergy data are estimated by the IEA.

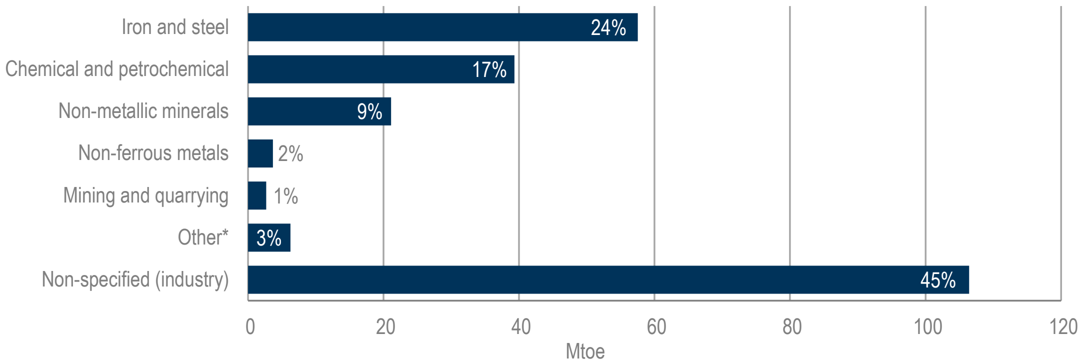
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Iron and steel is the largest energy-consuming industry sector, accounting for 23% of total industrial consumption (Figure 4.5). However, over 40% of industrial energy consumption is not specified by industry sector, which makes the size comparison uncertain. Iron and steel production consumes mainly coal products. Overall, coal accounts for 36% of total industrial energy consumption. Chemical and petrochemical industries are the second-largest energy consumers in the industrial sector. They mostly consume oil products and natural gas used for non-energy purposes as feedstock in the processes. Oil accounts for 23% of total industrial demand and natural gas 13%; both are steadily increasing. Iron and steel, chemical and petrochemical, and textile and leather are the industries with the highest electricity consumption. However, nearly half of all industrial electricity consumption is not specified by sector.

Industrial customers have around 80 GW of installed power production capacity at their sites for own-use. These captive power plants run on coal (54 GW or 68% of the total), natural gas (9.5 GW or 12%), diesel/fuel oil (3.5 GW or 4%) and renewables (bagasse, biomass, wind and solar) (15 GW or 16%).

India has an estimated 63.4 million micro, small and medium-sized enterprises (MSMEs), of which around a third are manufacturing companies (MMSME, 2019). There are more than 200 energy-intensive manufacturing clusters in the country. The energy use of MSMEs is estimated to be in excess of 68 Mtoe per year (BEE, 2019a).

Figure 4.5 Energy consumption in manufacturing industry sectors, 2017



The iron and steel, and chemical and petrochemical industries are the largest energy consuming industries, but 43% of all energy consumption in the sector is not specified.

**Other* includes food and tobacco, machinery, paper, transport equipment, construction, and wood and wood products.

Notes: Includes fuel consumption for non-energy use.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

India is the second-largest producer of cement and steel in the world. Production is driven by increasing domestic demand in various sectors such as housing, commercial and industrial construction, and overall infrastructure development.

In 2018 cement production capacity reached 502 Mt per year, up by 200 Mt (or 66%) since 2010. Actual cement production increased from 217 Mt in 2010 to 280 Mt in 2017 (Table 4.1). Production is expected to grow rapidly to reach 550-600 Mt per year by 2025. Per capita cement consumption in India is around 210 kg, far below the world average of 580 kg.

Table 4.1 Energy intensity indicators across cement, steel and aluminium

	Cement	Crude steel	Aluminium
Total installed production capacity	502 Mt (2018)	128 Mt (2017)	4.1 Mt (2017)
Projected production capacity	550-600 Mt (by 2025)	300 Mt (by 2030)	10 Mt (by 2030)
Production in the past	217 Mt (2010)	69 Mt (2010)	1.7 Mt (2016/17)
Current production	280 Mt (2017)	106.5 Mt (2018)	1.67 Mt (2017/18)
Consumption per capita	210 kg (world average: 580 kg)	66.2 kg (world average: 212.3 kg)	8.5 kg (world average: 11 kg)

Sources: Information on cement from WBCSD (2018), *Low Carbon Technology Roadmap for the Indian Cement Sector: Status Review*, and IBEF (2019a), *Iron & Steel Industry in India*; information on steel from IBEF (2018a), *Steel*, and WSA (2018) *Statistics*, and WSA (2019), "Global crude steel output increases by 4.6% in 2018"; information on aluminium from IBEF (2018b), *Metals and Mining*, and IBEF (2019b), *Metals & Mining Industry in India*, NITI Aayog (2018), *Need for an Aluminium Policy in India*, and TOI (2019), "Steps being taken to treble country's aluminium production: Tomar".

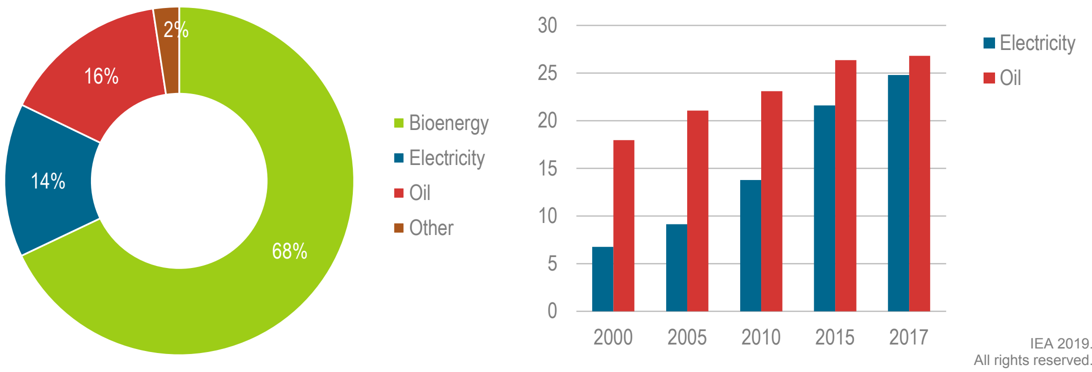
Steel production capacity surpassed 128 Mt in 2017, with actual production of crude steel[3] almost doubling from 69 Mt in 2010 to 106.5 Mt in 2018. By 2030 steel production capacity is expected to reach 300 Mt per year. India has low per capita steel consumption (66.2 kg, below the world average of 212.3 kg in 2017). Aluminium production stood at 1.7 Mt in 2016/17 and 1.67 Mt in 2017/18 and is forecast to grow to 3.33 Mt in 2019/20. Plans are underway to scale production up to in excess of 10 Mt by 2030. Per capita consumption in 2017 was 2.5 kg below the global average of 11 kg.

Residential

The residential sector accounts for nearly 30% of energy TFC in India. Residential energy consumption is largely dominated by traditional use of bioenergy, at 68% of the sector's total (IEA estimates), but the share provided by oil and especially electricity is growing (Figure 4.6). During 2012-17 residential electricity consumption increased by 53% and oil consumption increased by 17%, while bioenergy and waste declined by 14%. Household electrification has been a strong driver of electricity demand growth, reflecting a strong policy push: over half a billion people have gained electricity access since 2000. Higher income levels have allowed households to purchase more appliances: almost 40% of Indian households now own a refrigerator compared to 25% in 2010. Cooling systems are also a major driver of increasing electricity demand. The number of households in India owning an air conditioner has increased by 50% in the last five years. Nevertheless, India still has one of the lowest appliance penetration rates in the world.

[3] Includes all qualities: carbon, stainless, and other alloy.

Figure 4.6 Residential sector energy consumption by source, 2017, and growth in electricity and oil, 2000-17



Residential energy consumption is largely dominated by traditional use of bioenergy, but the share provided by electricity is growing.

Notes: Bioenergy data are estimated by the IEA.
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Services and agriculture

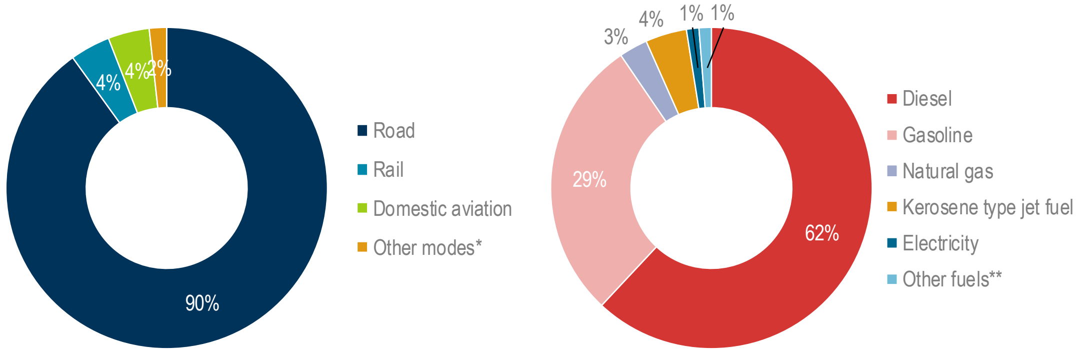
The service sector, including non-residential buildings, public services, agriculture, forestry and non-specified consumption, accounted for 12% of TFC in 2017. In the decade from 2007 to 2017, this energy consumption grew by 76%, the second most rapid growth after the transport sector. Electricity consumption more than tripled from 2000 and accounted for 50% of the sector's total energy demand in 2017 (Figure 4.7). The rest is mainly oil (22%), coal (14%) and bioenergy and waste (11%). Agriculture and forestry represented 42% of total consumption in the service sector.

Transport

Transport accounts for a relatively small share of TFC, 17% in 2017, which positions India at the lower end of the range among IEA member countries, in which transport accounts for 16-54% of TFC. However, India's transport energy demand is growing rapidly. Energy consumption for transport has more than doubled in ten years and more than tripled since 2000. In 2017 total transport energy demand reached 94 Mtoe. Oil products supplied 95% of total energy in the sector, mostly diesel and gasoline. Road transport accounted for 90% of total energy demand in domestic transport, followed by rail and domestic aviation (Figure 4.7).

About 3.4 million light duty vehicles (LDVs) were sold in India in 2017. The on-road stock stood at about 35.6 million, implying ownership of about 30 LDVs per 1 000 inhabitants (IEA, 2019c). India is the world's largest market for scooters and motorcycles, with sales exceeding 19 million per year. In 2018 sales of electric two-wheelers almost doubled to 54 800 compared to the previous financial year; they have been leading the electric vehicles (EV) market, estimates suggesting they account for 98% of the country's EV sales (NITI Aayog and Rocky Mountain Institute, 2019).

Figure 4.7 Energy consumption for transport by mode and fuel, 2017



Road transport accounts for the majority of transport energy demand and diesel is the most commonly used fuel.

**Other modes* of transport includes domestic navigation and gas pipeline transport.

***Other fuels* includes biofuels (biogasoline and biodiesel), fuel oil and liquefied petroleum gases.

Notes: Natural gas is used in road-based transport; electricity is still used primarily for rail.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

The average fuel consumption of LDVs is low at 5.6 litres of gasoline equivalent per 100 kilometres (Lge/100 km). This is principally due to the high market share of diesel LDVs and the small average vehicle size (IEA, 2019c). However, vehicle weight and footprint are on the increase and sport utility vehicles (SUVs) have already reached 33% of new car sales (IEA, 2018b).

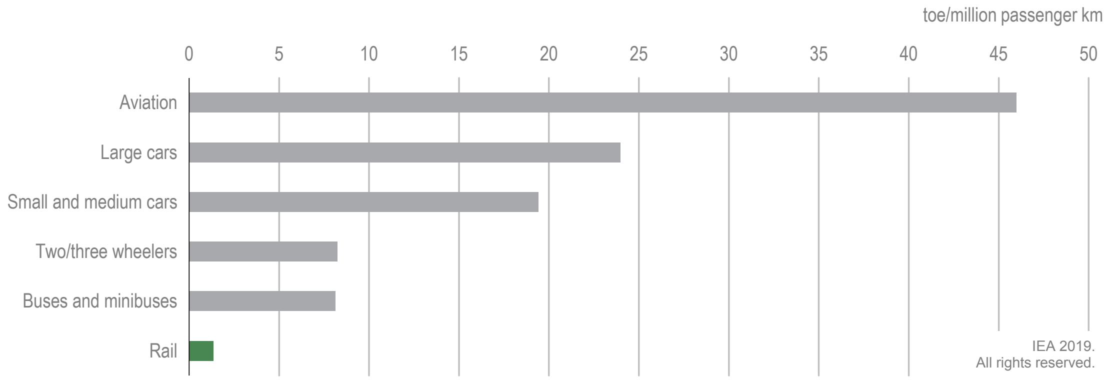
Over the past three decades India's road freight activity has increased more than tenfold. Its oil demand for road freight transport has seen the highest growth among all countries since 2000, increasing by a more than a factor of three (IEA, 2017b).

Between 2000 and 2017 use of rail intensified in India, with passenger transport activity (passenger kilometres travelled) increasing by around 200% and freight activity (tonne kilometres) by 150%. Rail activity in India is among the highest in the world, being second only to the People's Republic of China ("China") for passenger movements and fourth for freight movements. Rail is making an important contribution to limiting transport energy demand in India: in 2017 rail transport in India consumed 18 toe less per million passenger kilometres than small and medium-sized cars, and also almost 18 toe less per million tonne-kilometre than medium-sized freight trucks (Figure 4.8) (IEA, 2019d).

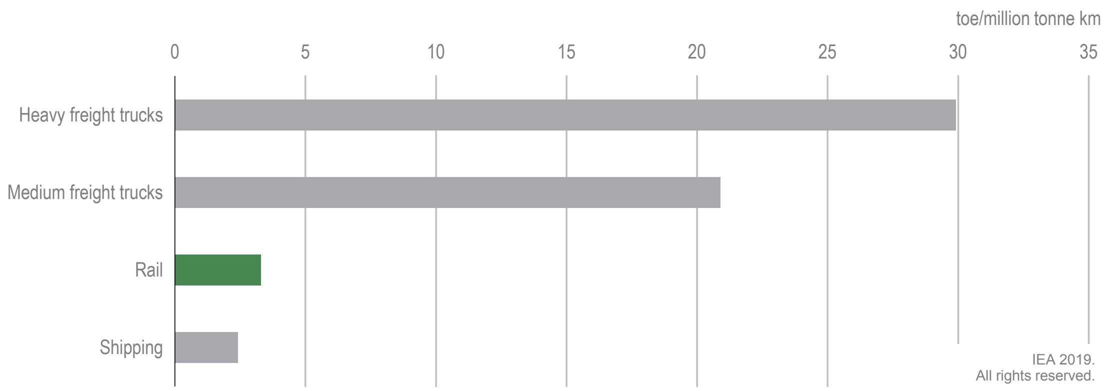
There is a significant degree of electrification of rail in India. All metro systems are electrified, 54% of conventional passenger rail activity relies on electricity (on a passenger kilometre basis) and 65% of total freight rail activity is powered by electricity (on a tonne-kilometre basis) (IEA, 2019d).

Figure 4.8 Energy intensity by transport mode, 2017

Passenger transport



Freight transport



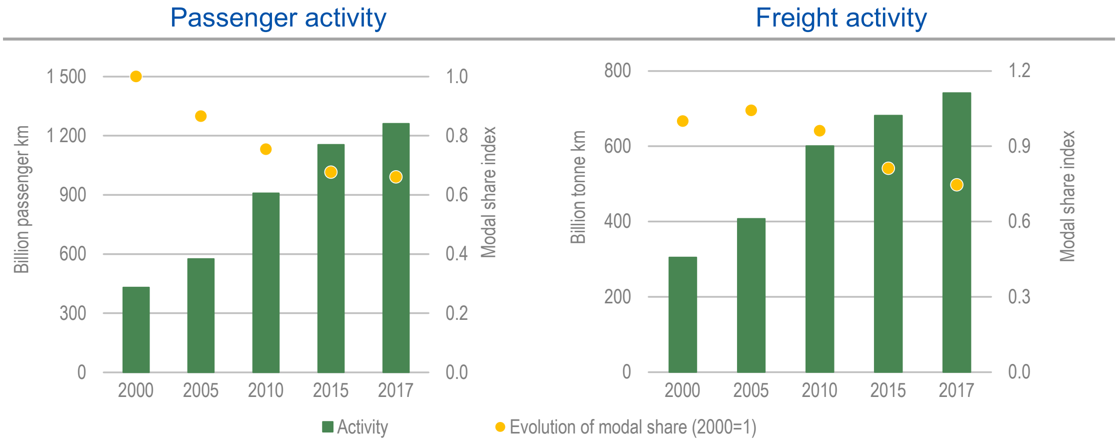
Rail is the most energy-efficient mode of passenger transport and the second most energy-efficient mode of freight transport after shipping.

Note: toe = tonnes of oil equivalent. Energy intensity of rail is calculated as the weighted average of all rail technologies.

Source: IEA (2019d), *Future of Rail*, www.iea.org/futureofrail/.

In recent years, while rail activity has been increasing, its share compared to other transport modes has been decreasing (Figure 4.9). Aviation activity is still low, but is set to increase – India is forecast to become the third-largest market globally by 2025 (IATA, 2018), thus introducing additional competition for rail on long-distance trips.

Figure 4.9 Evolution of passenger and freight rail transport activity and share of transport sector in India, 2000-2017



Passenger and freight rail activity in India has steadily increased over time, but at a slower rate than transport by other modes, decreasing rail's modal share.

Source: IEA (2019d), *Future of Rail*, https://www.iea.org/futureofrail/.

Policy framework and institutions

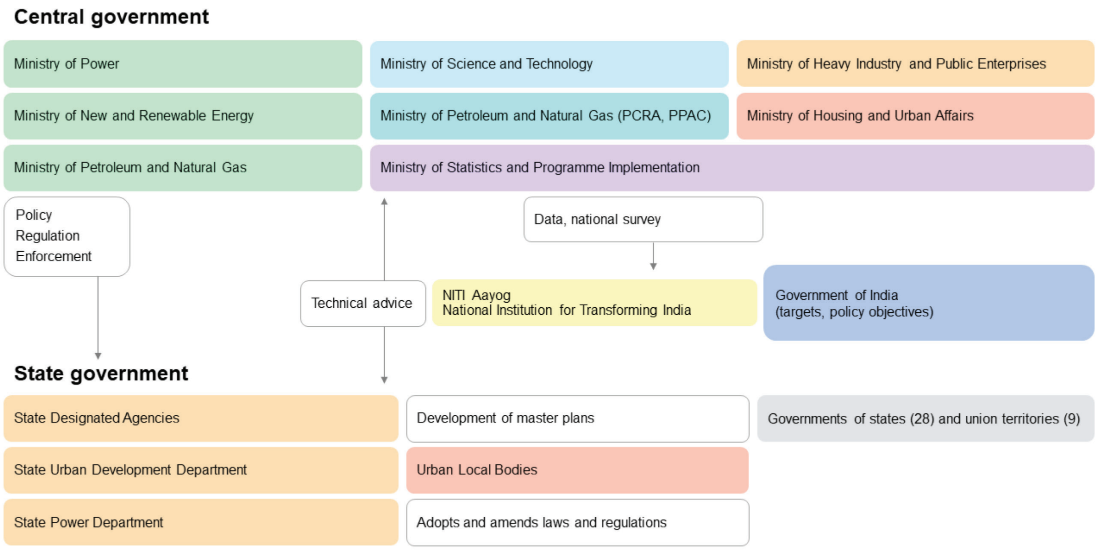
India has a well-developed policy and institutional framework for energy efficiency (Figure 4.10). The Ministry of Power (MoP) is responsible for policies in the electricity sector. The Bureau for Energy Efficiency (BEE), under the MoP, implements and regulates energy efficiency policies and programmes as set under the 2001 Energy Conservation Act. The act, amended in 2010, provides the basis for India's energy efficiency policy framework. It is reinforced through the National Mission on Energy Efficiency, one of eight missions under the 2008 National Action Plan on Climate Change. The MoP and the BEE take the lead in collecting and compiling energy efficiency data and developing indicators. India is currently undertaking work on the disaggregation of energy consumption by subsector and end use.

The National Institution for Transforming India (NITI Aayog) supports the government in assessing and formulating the national plans for the energy sector, as well as improving energy data collection and dissemination across the central and state governments. Line ministries such as the Ministry of Housing and Urban Affairs, Ministry of Heavy Industries and Public Enterprises, Ministry of Micro, Small and Medium-Sized Enterprises, and Ministry of Environment, Forests and Climate Change (MoEFCC) also play an important role in the development and implementation of energy efficiency policies.

In accordance with the Energy Conservation Act, states are obliged to set up state-designated agencies to support the implementation of energy efficiency policies and to establish State Energy Conservation Funds (SECFs). To date, 28 states have constituted SECFs and most states have provided a financial contribution. States have an important role to play in developing and enforcing critical energy efficiency standards and regulations, building institutional capacity, formulating policies, planning and implementing projects, extending financial support and creating markets for energy efficiency. State Electricity Regulatory Commissions (SERCs), power distribution companies (DISCOMS) and energy utilities are entrusted with implementing regulatory conservation measures and promoting energy efficiency programmes.

Established in 2009, Energy Efficiency Services Limited (EESL), a joint venture set up by four government-owned companies,[4] implements market-related activities of the National Mission for Enhanced Energy Efficiency.

Figure 4.10 Key institutions involved in energy efficiency policy making and implementation



Policies and programmes

India has a broad portfolio of energy efficiency policies and programmes, including regulation, market transformation, fiscal policies, incentive-based instruments, awareness-raising and awards to recognise achievements. In recent years India has launched a number of innovative programmes with far-reaching impacts. Apart from national and sub-national policies and programmes, a large number of energy efficiency projects supported by bilateral and multilateral programmes have facilitated the development of policies and measures.

NITI Aayog's draft National Energy Policy highlights energy efficiency as one driver to achieve its four key objectives: energy access at affordable prices, improved energy security and independence, greater sustainability and economic growth (NITI Aayog, 2017). In June 2019 the BEE published a draft national strategic plan for energy efficiency – Unlocking National Energy Efficiency Potential – which is under consultation. The plan covers the period 2017-31 and indicates potential energy savings in the range of 86.9-129 Mtoe by 2031 (BEE, 2019b).

[4] NTPC Limited, Power Finance Corporation Limited, Rural Electrification Corporation Limited and Powergrid Corporation of India Limited.

The central government has policies (missions) that specifically target energy demand growth:

- The Smart Cities Mission, launched in 2016, aims to develop 100 cities across the country. Priorities include reducing energy demand of existing buildings and enhancing the efficiency of new construction.
- The Atal Mission for Rejuvenation and Urban Transformation aims to establish efficient transport systems in 500 cities.
- India is the first country in the world to have a Cooling Action Plan. The Indian Cooling Action Plan (ICAP) was launched in March 2019 by the MoEFCC. The ICAP provides a 20-year perspective and outlines actions needed to provide access to sustainable cooling.

Industry

India has developed an innovative and unique energy efficiency programme for large energy-intensive industry that is successively being expanded to include more subsectors, including large commercial buildings and DISCOMs.

Developed by the BEE, the Perform, Achieve and Trade (PAT) scheme combines improvement targets with market-based incentives for strong performance. It is implemented on a rolling basis and has entered its third and fourth cycle. PAT sets mandatory energy intensity improvement targets per designated consumer (DC) in energy-intensive sectors. Every designated consumer has to carry out a mandatory energy audit by an accredited energy auditor within 18 months of first notification. Unlike other mandatory policies, PAT provides an incentive for DCs to exceed targets by allowing them to generate energy-saving certificates (ESCerts) that can be traded with other DCs that were not able to meet their energy intensity target. The first PAT cycle (2012-15) covering 478 designated consumers resulted in:

- INR 1 billion (USD 0.01 billion) worth of trading by the end of the period.
- Savings of 8.67 Mtoe (1.25% of total primary energy supply), representing about INR 95 billion (USD 1.35 billion) in energy costs per year.
- Reductions in CO_2 emissions of around 31 Mt (1.9% of total CO_2 emissions).
- Cumulative investment by the industry in energy-efficient technologies of INR 261 billion (USD 3.67 billion), with fertilisers in the lead followed by iron and steel industry sector (IEA, 2018b; Powerline, 2018; BEE, 2018).

The results of the second cycle of PAT, covering 621 DCs with the aim of saving almost 8.9 Mtoe, are currently being assessed. This also includes 208 thermal power plants, with 87 state-owned power plants that have taken energy efficiency measures to meet performance targets.

Programmes are ongoing to support energy efficiency in MSMEs and industrial clusters. For instance, the government's Zero Defect and Zero Effect (ZED) initiative, launched in 2016, encourages the exchange of best practices in micro, small and medium-sized enterprises to reduce waste of natural resources, thereby reducing energy waste.

An online knowledge exchange platform has been set up to facilitate peer-to-peer learning and exchange of best practices, and raise awareness about innovative approaches to energy management and new and upcoming technologies (knowledgeplatform.in). Access to finance is facilitated through a partial risk guarantee and a venture capital fund for energy efficiency. Financial assistance and low-interest loans are available for energy efficiency measures in MSMEs.

Buildings

India is improving the energy efficiency of buildings through mandatory building energy codes and voluntary rating schemes, as well as through policies and programmes to improve the efficiency of appliances and equipment.

Initiated by the BEE, India has had mandatory energy building codes for commercial buildings since 2007. An update to India's Energy Conservation Building Code (ECBC) for commercial buildings was announced in June 2017.[5] The model building code prescribes energy performance standards and includes requirements for builders, designers and architects to integrate passive design principles and renewable energy sources into building designs. New buildings must demonstrate minimum energy savings of 25% (compared to a typical building) to be code-compliant. Buildings that achieve energy savings of 35% earn "ECBC Plus" status and those that achieve savings of 50% get "Super ECBC" status. There are three compliance pathways: prescriptive, building trade-off and whole-building performance method. The code comes into force upon notification by the states. The sub-national governments have the flexibility to modify the code to suit regional or local needs and are responsible for enforcement and verifying compliance (BEE, 2019c). The BEE is working with a number of states to speed up the uptake of the code.

Full adoption and enforcement of ECBC 2017 for new commercial buildings could achieve an estimated 50% reduction in non-residential building energy use by 2030. This corresponds to an annual reduction of 300 TWh and peak demand reduction of over 15 GW, leading to expenditure savings of INR 350 billion (or USD 4.93 billion) and CO_2 reduction of 250 Mt (PIB, 2017).

The BEE has developed a voluntary Star Rating Programme for buildings, which is based on the actual performance of a building expressed in kWh per square metre (m^2) per year. Currently, labelling is available for four categories of buildings (day use office buildings, business process outsourcing buildings, shopping malls and hospitals). Around 230 buildings as of June 2019 are star rated (BEE, 2019c).

In 2018 India took a significant step forward with its first ECBC for residential buildings, which has been developed to enable simple enforcement while improving occupant thermal comfort and enabling the use of passive systems. The BEE is working with a number of states to accelerate the uptake of the code. A residential labelling scheme was announced in February 2019.

The 2017 National Energy Efficient Buildings programme aims to retrofit 20 000 large public and private buildings with more efficient appliances and equipment by 2020. As part of the programme, buildings are equipped with advanced building management systems to track power consumption in real time and identify options to reduce energy waste. The system also provides data-driven insights to optimise energy management strategies and minimise operational costs. It can give facility managers a comparative snapshot of energy

[5] The code applies to buildings with connected load of 100 kilowatts or contract demand of 120 kilovolt amperes and above. It also covers alterations if the altered part of the building or system exceeds 100 kilowatts or 120 kilovolt amperes of load demand.

use and energy cost, and provide an overall energy sustainability report (EESL, 2019a). A National Energy-Efficient Building Dashboard provides information on results (www.eeslbeep.com). To date almost 10 000 buildings have been retrofitted. The programme has enabled annual savings of 85.6 gigawatt hours (GWh) and reduced buildings' operating costs by USD 11.3 million.

Guidance, tools, capacity building and peer-to-peer learning are delivered by the Building Energy Efficiency Project set up by the MoP and the Swiss Federal Department of Foreign Affairs (www.beepindia.org). The Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE), which is a risk-sharing mechanism, has been used for projects in government buildings and private buildings (commercial and multi-storey residential buildings).

India is also progressing energy efficiency through green building rating schemes. These are voluntary schemes promoting sustainable new projects and retrofits. Rated projects comply with national building codes and standards including the ECBC. Rated buildings typically use 30-40% less energy than those that are non-rated. With a green building rated floor space of around 600 million m^2, India has the second-largest green building footprint in the world (IGBC, 2019a). The MoEFCC and several state governments provide incentives for green building projects (IGBC, 2019b).

Appliances and equipment

India is improving the efficiency of its equipment and appliances through energy efficiency standards and labels, market-based programmes including bulk procurement models, and incentives for the manufacture of efficient appliances. Efficient use is promoted through regular awareness-raising campaigns, such as the recent campaign on setting air-conditioners at 24°C.

The BEE initiated an energy efficiency standards and labelling programme for equipment and appliances in 2006. The scheme covers 23 types of appliances and equipment, of which 10 are mandatory[6] and 13 are voluntary[7]. The requirements are periodically updated. The labels consist of 1-5 stars where 5 stars is the most efficient and 1 star corresponds to the mandatory energy performance requirement. The BEE has developed a mobile application to help consumers make energy-efficient purchasing decisions (www.beestarlabel.com/Home/MobileApp) and an online platform including an online product registry (www.beestarlabel.com). The BEE regularly conducts training for retailers and other stakeholders. Companies that produce non-compliant products are publicly named. According to a recent study conducted by the BEE, the programme resulted in savings of 40.46 TWh (excluding LEDs) in 2017 and in 18.7 TWh in the year 2018/19 (BEE, 2019d).

The Super-Efficient Equipment Programme (SEEP) was initiated by the BEE in 2013 with the aim of leapfrogging to an efficiency level of about 50% higher than market average. It provided a time-bound incentive to manufacturers to produce super-efficient equipment and sell it at a discounted price. The programme initially focused on ceiling fans.

[6] Frost-free refrigerators, direct cool refrigerators, tubular fluorescent lamps, fixed-speed room air conditioners, variable-capacity inverter air conditioners, room air conditioners (cassettes, floor-standing), electric geysers, colour televisions, distribution transformers, light-emitting diode (LED) lamps.

[7] Induction motors, agricultural pump sets, ceiling fans, domestic LPG stoves, washing machines, computers (notebooks, laptops), electric and magnetic ballast, office equipment (printer, copier, scanner, multi-function device), diesel engine-driven mono-set pumps for agriculture, solid-state inverters, diesel generators, chillers, microwave ovens.

India has achieved impressive results through bulk purchasing programmes. The Unnati Jyoti by Affordable LEDs for ALL (UJALA) programme has radically pushed down the price of LEDs available in the market globally and helped to create local manufacturing jobs to meet the demand for energy-efficient lighting. LEDs now cost less than INR 60 (1 USD). EESL has helped replace over 350 million lamps with LEDs, resulting in 45.5 TWh annual savings. The success of this procurement model is being replicated across different product categories. To date more than 2.2 million efficient fans have been deployed saving 0.2 TWh per year and 6.9 tubelights saving 0.3 TWh per year (MoP and EESL, 2019).

In 2017, in the first procurement round of air conditioners, the lowest-price bidder offered high-efficiency five-star air conditioners that can save 30-40% on a cooling electricity bill at a cost only slightly higher than that of the cheapest air conditioners on the market. Prices are expected to fall further as more air conditioners are procured and product manufacturers exploit the economies of scale that bulk procurement can induce. EESL's Super-Efficient Air Conditioning programme allows consumers to buy a super-efficient Air conditioners at prices that are comparable to the most energy-efficient ACs in the market, but reduce the cost of cooling by 50%.

In 2018 India had around 36 million air conditioners and by 2050 it is expected to have in the region of 1 billion (or 1 144 million units). Without major improvements in air conditioner energy efficiency, electricity demand for space cooling in buildings in India looks set to increase to nearly 1 350 TWh in 2050 and require an additional 800 GW of power generation capacity just to meet space cooling needs. About 70% of that growth is assumed to come from the residential sector (IEA, 2018c).

Policies to improve the energy efficiency of air conditioners could by 2050:[8]

- Reduce cooling electricity demand by 45%.
- Deliver more than 8 000 TWh of cumulative electricity savings.
- Save USD 295 billion in cumulative power generation investments. Reduce average per capita electricity costs for cooling by a third (IEA, 2018c).

By combining efficient air conditioners with building envelope measures, cooling energy demand could be cut by another 35% by 2050 (IEA, 2018c). In India, stronger requirements for air conditioners came into effect in January 2018, which will push the Indian market to greater levels of efficiency.

Municipalities

Launched in 2015, the Street Light National Programme aims to replace 35 million inefficient light bulbs used for street lighting in 100 Indian cities. EESL finances the upfront cost, which is recuperated through financial savings from lower electricity bills under a pay-as-you-save approach. To date more than 8.9 million light bulbs have been replaced, resulting in energy savings of almost 6 TWh/year (MoP and EESL, 2019).

As part of the Municipal Energy Efficient Programme, the Ministry of Housing and Urban Affairs is working with EESL to deploy energy-efficient pumps across 500 cities. There are

[8] According to the IEA Efficient Cooling Scenario as compared to the Baseline Scenario in IEA (2018c).

plans to conduct energy efficiency audits of more than 330 cities as part of the Atal Mission for Rejuvenation and Urban Transformation (EESL, 2019b).

Agriculture

Since the 1970s, agriculture in many Indian states has received subsidised electricity; in some cases electricity is even supplied for free. Much of this supply is unmetered. Generally, pumps used in the sector have low energy performance due to low pump efficiency, incorrect sizing, insufficient maintenance and power quality issues, contributing to water and energy wastage. Feeder separation (separating agriculture feeders from village feeders) to improve the estimation of agriculture consumption is ongoing. Several states plan to shift night-time consumption during the monsoon to the daytime to match it with solar PV generation.

India is implementing the world's largest agricultural demand-side management programme. Under the programme, inefficient agricultural pump sets are replaced with BEE 5 star-rated energy-efficient pump sets. There are more than 21 million grid-connected pump sets in India and their deployment is on the rise, with estimated annual additions of up to half a million per year (ICF International, 2016). Replacing these with more efficient pumps could enable electricity savings in the region of 4.3 TWh/year, cut subsidy expenditure by more than INR 227 billion (USD 3.2 billion) and avoid almost 35 Mt CO_2 (EESL, 2019a). EESL is working on replacing inefficient pump sets with high-efficiency models that have smart controls (enabling farmers to remotely monitor and control options to optimise energy and water use) at zero cost for farmers. The replacement also entitles farmers to free repair and maintenance during the first five years. The programme aims to distribute 200 000 BEE star rated pump-sets to the farmers. To date, the programme has achieved the replacement of around 2 000 pump sets, with 2 500 replacements underway (EESL, 2019a).

Transport

The government is focusing on decarbonising the transport sector through increased efficiency, cleaner fuels, electric mobility and modal shift.

In January 2014 the government set CO_2 emission targets for LDVs at the equivalent of 130 grammes of CO_2 per kilometre (gCO_2/km) in 2017 and 113 gCO_2/km in 2022. In 2016 it then published Bharat Stage (BS) VI emission standards for motor vehicles, effective April 2020, on a par with EURO VI standards. They address all major vehicle types and include provisions that will ensure clean fuels are available alongside the introduction of new low-emitting vehicles.

In August 2017, as one of the first countries in the world, India published fuel efficiency standards for commercial heavy-duty vehicles. Phase 1 came in effect in April 2018, while Phase 2 will become effective in April 2021.

India is actively promoting the uptake of electric and hybrid vehicles. The efficiency of an electric vehicle (EV) is typically around 60% (increasing up to about 77% if regenerative braking is included), compared to around 20% efficiency for combustion engines.

The National Electric Mobility Mission Plan (NEMMP) 2020 was launched in 2012. In May 2017 NITI Aayog outlined a vision for the transformation of mobility, proposing a set of solutions to accelerate India's leadership in advanced mobility. With a 2030 horizon the government is aiming for 30% of new sales of cars and two-wheelers to be EVs (today they make up less than 1%). In 2018 the government launched a National E-Mobility Programme to be implemented by EESL, which will focus on public procurement to facilitate demand creation for EVs. In line with the government's aim to promote the electrification of public transport, 10 Indian cities have launched tenders for electric buses.

In December 2018 the MoP issued new guidelines for building charging infrastructure for EVs and the BEE has been mandated to be the "nodal" agency. The guidelines include technical standards and rules for permitting. The government adopted the Faster Adoption and Manufacturing of (Hybrid and) EVs (FAME) scheme in 2015, with a budget of INR 8.95 billion (USD 130 million) to provide subsidies for electric two- and three-wheelers, hybrid cars, electric cars and buses. The scaled up FAME II, effective from April 2019, has a budget of over INR 100 billion (USD 1.4 billion) to be used for upfront incentives for the purchase of EVs (INR 95.96 billion or USD 1.35 billion) and for supporting the deployment of charging infrastructure (INR 10 billion or USD 0.14 billion).

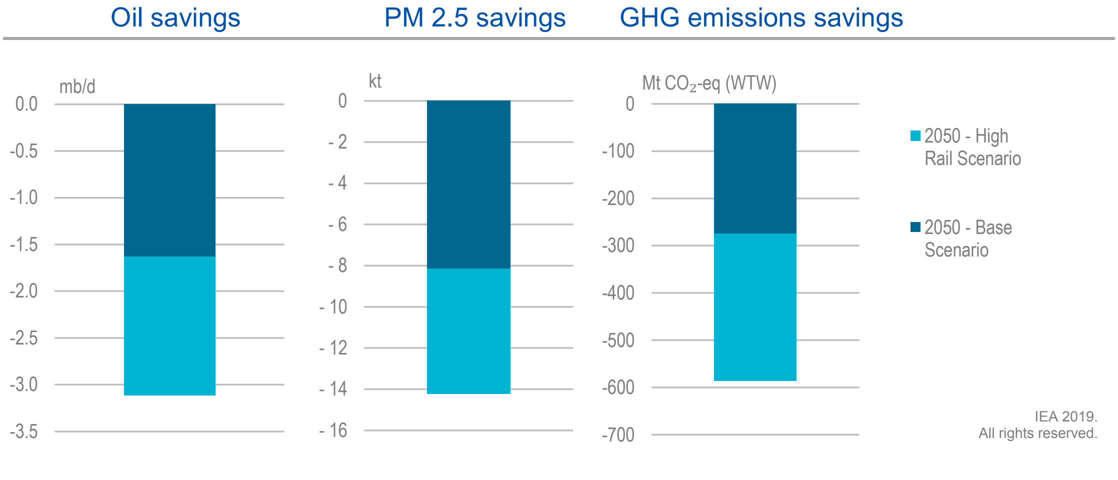
Rail is the most energy-efficient mode of passenger transport and the second most energy-efficient for freight transport after shipping. Indian Railways is spearheading a wide range of ambitious undertakings. Construction has started on the first high-speed rail line. The total length of metro lines is planned to more than triple in the coming decade. Two dedicated freight corridors are planned for 2020. The GoI has also approved the ambitious target of completely electrifying its broad-gauge network[9] by 2022 (IEA, 2019d). Based on recent IEA analysis of enhancing the role of rail in the transport sector, by 2050 India could: reduce oil demand by 3.1 million barrels per day (mb/d), save around USD 60 billion on fuel expenditure and reduce GHG emissions by 585 Mt CO_2-eq and PM 2.5 emissions by 14 thousand tonnes (kt) per year (see Figure 4.11).[10] India can achieve these benefits by:

- Mobilising investment to modernise the railway network and overcome infrastructure bottlenecks on the most utilised routes.
- Maintaining the affordability of passenger rail while modernising and improving passenger rail services and safety. Revenues for the required improvements should be generated from sources beyond ticket pricing, such as land value capturing.
- Ensuring completion of the envisaged construction of high-speed rail infrastructure between the largest cities (Golden Quadrilateral) to provide a competitive low-carbon alternative to transport by air.
- Phasing out the cross-subsidisation scheme (from freight rail to passenger rail) to boost the competitiveness of freight rail.

[9] India has three rail networks: broad gauge, metre gauge and narrow gauge.

[10] Benefits of IEA Base Scenario plus IEA High Rail Scenario in IEA (2019d).

Figure 4.11 Energy savings and associated benefits of rail by 2050



Note: WTW = well to wheel.
Source: IEA (2019d), *Future of Rail*.

Assessment

As the Indian economy continues to prosper, energy efficiency improvements will be increasingly crucial to manage energy demand and emissions. Energy efficiency policies are an effective and strategic means of supporting multiple policy objectives: facilitating increased energy access, enabling greater energy services to households and businesses, fostering growth of energy-efficient components, products and service markets, reducing negative climate and environmental impacts and strengthening energy security.

India's size, scale and stage of development has allowed large and timely cost-effective energy savings and has stimulated a national market for energy-efficient products and services that could form the basis for export opportunities. India has already demonstrated an impressive ability to develop, deploy, replicate and scale up innovative, market-based approaches to energy efficiency. The country has an excellent basis for further energy efficiency policy innovation and market creation, including a strong community of non-governmental organisations, research institutes and think tanks active in the area of energy efficiency. India has competitive appliance, equipment, electronics and automotive industries and is a global leader in information technology and related services. By stimulating the development and use of digital solutions for energy efficiency,[11] India can grow its leadership in this area and access rapidly expanding markets across the world.

A commendable step in paving the way to reduce energy demand from cooling is the Cooling Action Plan, the first of its kind globally. It is further laudable that joint implementation of the plan has been helped by discussions between the Department of

[11] Such as: smart meters; energy use displays; home energy management systems; buildings energy management systems; metering, monitoring and management systems for industrial energy use; systems for automated demand response; consumer interfaces; and digital applications for energy efficient choices and behaviour.

Science and Technology, MoEFCC and the BEE held in May 2019 to discuss R&D and innovation in cooling and refrigeration.

Co-ordination, institutional capacity and data

The ongoing process led by the BEE to develop a national energy efficiency strategy is an excellent opportunity to develop a clear vision, set short-, medium- and long-term targets, assign responsibilities, and identify actions and steps for achievement.

Governments play a crucial role in establishing conducive framework conditions for energy efficiency by co-ordinating policies across all sectors to address issues like data collection, pricing and market barriers. Co-ordination across ministries, agencies, electricity regulators and DISCOMs and sub-national governments is essential. The government should consider periodic evaluation of institutional capacity, policies, programmes and markets – including at the state level – to identify best practices and promote cross-learning. To capitalise on energy efficiency opportunities, further efforts should be made to integrate and prioritise energy efficiency in energy system planning and urban planning, as well as in missions, plans, strategies and initiatives such as Make in India, Smart Cities Mission, Atal Innovation Mission and Atal Mission for Rejuvenation and Urban Transformation.

As the nodal agency for energy efficiency, the BEE develops strategies, policies and programmes, collects and analyses data, administrates implementation and assesses results, implements a wide range of projects, actively co-ordinates ongoing initiatives, carries out capacity building at national and sub-national levels, provides training and accreditation and organises awareness-raising campaigns. Given the scope of activities already underway, the size of the country and the growing importance of energy efficiency, further resourcing of the BEE warrants attention.

Reliable and timely data on energy end uses, markets, technologies and efficiency opportunities in all sectors contribute to the development of effective energy efficiency strategies and policies.

In recent years there has been significant improvement in data compilation to support effective energy efficiency strategies and policies in India. Data gaps have been identified, co-ordination has been strengthened and plans made to develop an energy data management system and platform. However, data gaps still remain, notably data on the industrial sector (where more than 40% of energy use and more than 50% of electricity use is not specified), data on traditional biofuel use, data on energy demand in agriculture and activity data across all sectors. Further efforts are warranted to improve the availability of disaggregated data to enable data-driven policy making and monitoring of energy efficiency. It is essential to enhance co-ordination among organisations to maximise resources and data quality. As part of a strategy to adopt best practices in energy efficiency data collection and management, the government could consider piloting a voluntary submission of the IEA energy efficiency questionnaire and continuing to work with the IEA on energy efficiency indicators.

The GoI should increase efforts to monitor and evaluate, and periodically update, energy efficiency policies and measures across all sectors. The GoI could consider mandating evaluation of programme effectiveness during and after implementation, with the results as input to subsequent decision making and planning.

Leveraging private-sector investments

The market potential for energy efficiency services in India is estimated to be between USD 10 billion and USD 35 billion per year. EESL, the GoI's national energy service company created under the MoP, has achieved outstanding success in developing business models, achieving economies of scale, enabling energy efficiency and attracting investment. However, in respect of the rest of the market, opportunities remain largely untapped with current combined revenues of energy service companies only being USD 150 million (excluding EESL's revenues) (AEEE, 2017). Meanwhile, the same market has exceeded USD 16 billion in China and USD 7.6 billion in the United States. As regards focus, almost all projects are in the industrial sector, with public-sector energy efficiency projects accounting for only 1%. Indian energy service projects deliver on average 20% energy savings (IEA, 2019e).

The central and state governments have the opportunity to accelerate energy efficiency implementation across all end uses by taking concerted action to remove barriers and help create market demand for energy services. This could include facilitating access to equity and venture capital, risk mitigation through, for example, guarantee schemes and by providing incentives both for energy service companies and customers.

Further efforts to improve the investment climate for energy efficiency projects are warranted. Avenues to explore include raising investor confidence in energy efficiency projects,[12] public–private partnerships,[13] public–private platforms to identify solutions,[14] development of tools for financial institutions[15] and measures to help de-risk energy efficiency investments.[16] The value of approaches such as energy efficiency insurance could also be explored.[17]

Industry

India has made impressive progress in the area of industrial energy efficiency with its innovative PAT scheme, which is expected to substantially curb industrial energy demand with increased stringency and roll-out to new sectors. International, national and sub-national benchmarking and development of sectoral technology roadmaps could further stimulate energy efficiency.[18]

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[12] E.g. US Investor Confidence Project http://www.eeperformance.org/; EU Investor Confidence Project http://europe.eeperformance.org/.

[13] E.g. European Energy Efficiency Fund https://www.eeef.eu/objective-of-the-fund.html.

[14] E.g. Energy Efficiency Financial Institutions Group http://www.eefig.com/.

[15] E.g. tools on underwriting http://www.eefig.com/.

[16] E.g. de-risking via data on projects http://www.eefig.com/index.php/deep.

[17] E.g. Green Finance for Latin America and the Caribbean Energy Savings Insurance programme https://www.greenfinancelac.org/our-initiatives/esi/.

[18] In 2012 the IEA developed a low-carbon technology roadmap for the Indian cement industry, which has proved to be a useful tool in charting the way towards the development and uptake of sustainable technologies and processes: IEA and WBCSD (2012), https://webstore.iea.org/technology-roadmap-low-carbon-technology-for-the-indian-cement-industry. Long-term targets allow for tracking progress – as done in 2018 by the Cement Sustainability Initiative in India, showing that the sector has achieved the 2020 performance objective for emissions intensity reduction three years ahead of schedule and outlining further steps needed to reach the 2050 objective; WBCSD (2018) https://docs.wbcsd.org/2018/11/WBCSD_CSI_India_Review.pdf. Further examples of roadmaps include for example the Netherlands' chemical sector https://www.vnci.nl/Content/Files/file/Downloads/VNCI_Routekaart-2050.pdf, European steel sector https://www.estep.eu/assets/SRA-Update-2017Final.pdf.

To further complement the PAT scheme and promote energy efficiency in companies not covered by the programme, the GoI should consider incentivising or mandating the uptake of energy management systems and provide the tools to facilitate implementation. International experience shows that energy management systems such as ISO 50001 can reduce company-level demand by 10-30% within the first years of adoption and continue to lead to successive energy savings. By the end of 2017 only 1 613 sites in India had ISO 50001 certification compared to more than 30 000 in Germany alone (ISO, 2018), where uptake has been promoted through tax incentives.

The GoI could also consider incentivising the use of energy management information systems, which are digital solutions that enable real-time monitoring and management of energy use. Implementation of such systems in industry show on average 10–20% reductions in energy use just from providing a better understanding of how energy is used on the site and from equipment and process optimisation. Real-time monitoring of energy savings could also be of benefit in terms of reporting, measurement and verification of savings within the PAT scheme and other programmes.

Designing national programmes that effectively reduce MSME energy demand is challenging, especially considering the scale of the sector in India, with more than 63.4 million MSMEs. The cluster-based approach used in India offers economies of scale in effort and technology replacement. The GoI could consider measures to incentivise other actors with better access to MSMEs, such as state and local governments and industry associations, to work with them on energy efficiency. A further option could be to leverage ongoing initiatives such as the ZED initiative and the Make in India initiative and ensure that energy efficiency is prioritised.

The GoI could also consider expanding the coverage of its mandatory minimum energy performance standards and labels to industrial equipment such as electric motors (currently they have been voluntary at the IE2 level since 2012). India could consider the benefits of leapfrogging to higher IE levels.[19] Mandatory minimum energy performance requirements should be extended to other industrial equipment such as compressors, pumps, fans and boilers.

Buildings

About 75% of the buildings stock expected to be standing in India in 2030 has yet to be built. Significant opportunities therefore exist to reduce future escalations in energy demand by ensuring that new buildings are increasingly more efficient. A lack in adoption and enforcement of building energy codes could lock in inefficiency and unnecessary energy demand for the next 40-50 years (GBPN, 2019).

Improving the efficiency of the existing building stock and enforcement of compliance remains equally important. With its building energy codes, India has a solid regulatory framework, but implementation warrants further attention. By mid-2019, 12 states and 1 union territory had notified the GoI of ECBC implementation for commercial buildings and only 9 states had covered significant ground to incorporate ECBC for commercial buildings in municipal by-laws (AEEE, 2018). A number of states have started working on the incorporation of ECBC for residential buildings.

[19] Canada, Mexico, the United States, South Korea and the European Union already require IE3 in their minimum energy performance standard.

India has the opportunity to create a robust market for energy-efficient construction services, and energy-efficient and affordable building materials, equipment and appliances. Important steps to create demand include ramping up the adoption and enforcement of building energy codes and successively increasing their stringency, with a long-term aim of zero-energy buildings, while in parallel initiating activities to make businesses aware of the market opportunities associated with energy efficiency.

To support implementation, increased focus is warranted on the development of test standards for building components, support for the creation of building material testing laboratories, capacity building at sub-national level and along the whole building value chain, and creating a cadre of ECBC professionals. Opportunities exist to share experiences and replicate best practices among states and urban local bodies. For example, Hyderabad has developed an online energy code compliance system that speeds up and facilitates building code implementation and verification of compliance. Also the development and dissemination of case studies on compliant buildings would be a useful tool to increase engagement, particularly those showing that energy efficiency does not raise building costs substantially.

About 30% of the total commercial space in India is owned by the public sector. Leveraging public procurement and projects would contribute to the improved performance of buildings and help create domestic markets and capabilities. Regulatory options that could be considered are to mandate energy efficiency retrofit requirements (including the building envelope) for all public buildings and mandating that all new public building projects are designed to be at least Super ECBC Buildings. The National Energy Efficiency Buildings Programme is already starting to achieving economies of scale in efficient appliance and equipment retrofits and is promoting the uptake of advanced energy management systems for buildings.

The government should consider incentives to promote the uptake of the Energy Star rating label for commercial buildings, and the new residential buildings energy efficiency label. To further promote the energy efficiency of the building stock, the government could consider mandatory building energy auditing and reporting requirements as established in, for example, the European Union. The government could also support the development of tools that help convey the value of efficient buildings to relevant stakeholders along the lines of, for instance, the Chinese Commercial Building Analysis Tool for Energy-Efficient Retrofits.

To expedite progress and capture opportunities, India should consider developing national and sub-national building energy roadmaps. Roadmaps outline improvements to codes and standards over time with specific implementation and compliance goals, targets for energy efficiency within urban planning, and actions needed to improve the efficiency of existing buildings and transition towards net-zero energy consumption buildings.[20] A clear trajectory and policies to bring about zero-energy buildings could further boost innovation and grow markets for technologies and services.

[20] The IEA is working with the Global Alliance for Buildings and Construction to develop a template based on international best practices and methodologies that can be used as a basis for developing country-, state- or city-level building energy roadmaps.

Appliances and equipment

Despite surging demand for appliances, India's ownership rates are still among the lowest in the world (IEA, 2018c). Appliance ownership is expected to increase dramatically over the coming decades. Efforts to increase efficiency need to be scaled up to counteract escalating electricity demand. One of the most pressing areas is space cooling. Given that India's building stock continues to increase at a rate faster than anywhere in the world and the air conditioner market braces for a rapid increase in penetration, now is the critical window of opportunity to mitigate adverse impacts through timely policy interventions. Looking ahead, it is crucial to ensure that minimum energy performance standards and labels not only keep up with market developments, but also set a clear trajectory towards best available technologies or even beyond.

Further energy efficiency opportunities can be captured by ensuring that energy efficiency is a priority in urban planning and that options such as reflective surfaces, green and blue zones and shading to reduce cooling demand are utilised to counteract the escalation in energy use for cooling.

Moreover, scope exists to ramp up the stringency of mandatory energy performance standards and accelerate the shift from voluntary to mandatory standards. For instance the United States has specified future standards beyond the most efficient products on the market, thereby stimulating innovation. There is also significant scope for expanding the coverage of the standards and labelling programmes – for example China's programme covers more than 80 products and the US programme covers more than 60 categories of products.

Through its programmes for bulk procurement of appliances and equipment, India has demonstrated how policies and programmes can effectively create markets for energy-efficient products and bring down prices. India has the opportunity to further boost the development, manufacturing and sale of efficient appliances, equipment and components to access a greater share of internal and export markets. The opportunity is there to ensure that energy efficiency is a focus area of the Make in India initiative.

Scaling up the roll-out of smart meters coupled with energy monitoring and management functionalities will stimulate end-user energy efficiency. Together with demand response-enabled appliances, [21] these can lay the foundation for automated demand-side management interventions that will be needed to avoid peak power disruptions and reduce the investment required in peak generation capacity.

International experience indicates that insufficient compliance and enforcement of appliance and equipment standards and labelling programmes can result in 25-50% lower energy savings than projected (CLASP, 2019). The effectiveness of the Indian standards and labelling programme could be boosted by increased capacity building at the state level, increased check testing and challenge testing, coupled with expansion of laboratory and testing facility capacity and further efforts in label compliance.

[21] There are a variety of ways to enable automated demand response. Irrespective of approach chosen, standards and communication protocols need to be developed or selected. There are opportunities to build on existing progress, for example, from Australia (Australian Standard AS/NZS 4755), Japan (Echonet), International Electrotechnical Commission (IEC), and Open ADR Alliance.

India has been able to drive energy efficiency and clean cooking though its very successful liquified petroleum gas (LPG) programmes (PAHAL, Give it up, PMUY). LPG cookstoves are not only more energy efficient (achieving 60% efficiency) than kerosene stoves (35% efficiency) and wood stoves (10% efficiency), they also significantly reduce indoor air pollution.

Municipalities

Energy efficiency holds untapped potential for municipal budgets to be more cost-effective. Local action is crucial to improve energy efficiency and transition towards more sustainable energy systems. The national programmes on municipal street lighting and water system efficiency are excellent initiatives that should be scaled up. The BEE, together with partners, created a comprehensive manual on how to develop municipal energy efficiency projects in 2008 (BEE, ASE and IFC, 2008). An update could include lessons learned, success stories and new approaches, and could be a valuable tool in further promoting municipal energy efficiency.

Efforts could be made to highlight energy efficiency opportunities in an urban planning context, including the identification of how energy efficiency can contribute to key objectives and goals such as reducing operating expenses and the cost of delivering municipal services, reducing air pollution, improving access to clean cooking and promoting economic growth. This could lay a foundation for the development of local energy efficiency plans, plans for efficient water management, cooling action plans, building energy roadmaps and sustainable mobility strategies.[22] Barriers and capacity limitations need to be tackled that prevent municipalities from undertaking energy efficiency projects, such as limitations on the ability to access finance, utilise energy company services or conduct investment-grade energy audits.

Agriculture

The viability of the agricultural sector is of utmost importance in India. Energy efficiency can play a role in reducing waste and improving productivity in the sector. The GoI is starting to address these issues through its ambitious pump replacement programme, but results to date have been limited. Regular feeder and distribution transformer metering, regular energy audits and a periodic survey of pump sets could provide more reliable data

[22] Resources of interest include:

Energy Cities (2018), *Local Energy and Climate Roadmaps – 5 City Visions for 2015*, http://www.energy-cities.eu/IMG/pdf/local_energy_climate_roadmaps_final.pdf;

EPA (Environmental Protection Agency) (2017), *Energy Efficiency in Local Government Operations*, https://www.epa.gov/sites/production/files/2017-06/documents/ee_municipal_operations.pdf;

ESMAP (Energy Sector Management Assistance Program) (2012), *A Primer on Energy Efficiency for Municipal Water and Wastewater Utilities*, https://openknowledge.worldbank.org/handle/10986/18060;

EPA (2015), *Energy Efficiency in Water and Wastewater Facilities*, https://www.epa.gov/sites/production/files/2015-08/documents/wastewater-guide.pdf;

ADB (Asian Development Bank) (2014), *Urban Water Supply and Sanitation in Southeast Asia*, www.pseau.org/outils/ouvrages/adb_urban_water_supply_and_sanitation_in_southeast_asia_a_guide_to_good_practice_2014.pdf;

SUTUP (Sustainable Urban Transport Project) (2019), *Sourcebook Modules and Implementation Guides*, www.sutp.org/en/resources/publications-by-topic/sutp-sourcebook-modules.html;

ITF (International Transport Forum) (2017), *Integrating Urban Public Transport Systems and Cycling*, www.itf-oecd.org/sites/default/files/docs/integrating-urban-public-transport-systems-cycling-roundtable-summary_0.pdf;

ITF and CBP (Corporate Partnership Board), *Shared Mobility – Innovation for Liveable Cities*, https://www.itf-oecd.org/sites/default/files/docs/shared-mobility-liveable-cities.pdf.

on agricultural electricity consumption and enable the development of further targeted and effective energy efficiency interventions. As electricity consumption in agriculture remains heavily subsidised with low or special electricity tariffs, feeder separation is very helpful as part of subsidy reform.

Transport

Transport accounts for a relatively small share of total energy consumption, but is growing rapidly. Strong economic growth will further increase freight activity (IEA, 2019d). The GoI is already making strong efforts to minimise the impact of this inevitable growth. India has taken commendable steps in terms of fuel efficiency regulations. The efficiency of road transport could be further improved by complementary measures, such as efficiency standards for tyres, promoting eco-driving, information and awareness campaigns and regular mandatory inspections for existing and new vehicles.

The increased ambition in the second phase of FAME is laudable. Complementary measures may still be needed to address the high upfront purchase price of EVs, boost investment in EV manufacturing, ensure sufficient availability of charging infrastructure and improve the efficiency of EVs. Passengers can be encouraged to use public transport by improving its efficiency, quality, convenience, safety and cost-effectiveness. Dedicated lanes for buses, bicycles and pedestrians, improved bus routes and modernised railways can help ensure high levels of public transport use. Personal vehicles can be discouraged through differentiated vehicle taxation (e.g. “feebates”) and increased fuel taxes at a national level, as well as parking restrictions, travel bans in city centres and congestion and road charging at the regional and municipal levels of governance.

The GoI is making significant efforts to modernise the rail transport system in India and to make it able to respond to the booming demand for mobility in India. India could achieve significant energy savings by further stimulating transport modal shift from road and aviation to rail.

Recommendations

The Government of India should:

- ☐ Improve the availability, accessibility, consistency and timeliness of energy end-use data for all sectors, develop indicators and ensure the consistent evaluation of energy efficiency measures.
- ☐ Together with the states, improve the framework for implementing, enforcing and evaluating energy efficiency policies and programmes.
- ☐ Besides broadening and deepening the PAT scheme to include more sectors and actors, take measures to increase the uptake of energy management systems and support the development of sector-specific energy efficiency or low-carbon roadmaps.
- ☐ Together with states, fast-track the adoption and enforcement of building energy codes for commercial and residential buildings and develop a clear trajectory towards zero-energy buildings.

- Increase the rate at which voluntary equipment and appliances standards and labels become mandatory, include more equipment and appliances in these standards and set a stringent long-term path for best-available technologies to become the norm, particularly for equipment with high energy use such as air conditioners and motors.
- Ensure the enforcement of fuel efficiency standards and continue to strengthen standards for all road vehicles, while encouraging shifts towards more efficient and low-carbon transport modes.
- Develop a set of incentives and support measures to increase the demand for energy services.
- Assign roles, responsibilities and mandates for the implementation the India Cooling Action Plan and develop indicators and time-bound targets to track progress.

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5. Renewable energy

Key IEA data

(2017*)

Renewable energy in TPES: 206.5 Mtoe, 23.4% of TPES (IEA total: 9.9%)

Renewable electricity: 263.5 TWh, 17.2% of electricity generation (IEA total: 24.6%)

Bioenergy and renewable waste:** 186.8 Mtoe (21.2% of TPES) and 44.6 TWh (2.9% of electricity generation)

Hydro: 12.2 Mtoe (1.4% of TPES) and 141.8 TWh (9.3% of electricity generation)

Wind: 4.4 Mtoe (0.5% of TPES) and 51.1 TWh (3.3% of electricity generation)

Solar: 3.1 Mtoe (0.4% of TPES) and 26.0 TWh (1.7% of electricity generation)

*Bioenergy data are International Energy Agency (IEA) estimates.

**India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. So, the statement: "In 2017, renewable electricity was 263.5 TWh" refers to the data India has collected (and supplied to the IEA) from 1 April 2017 to 31 March 2018. IEA data do not distinguish between large and small hydropower.

Overview

The Government of India (GoI) has set ambitious renewable electricity targets for the short to medium term. By 2022 the country aims to have 175 GW of installed renewable electricity capacity. In 2018 the GoI announced an increased ambition of 227 GW renewable capacity by 2022 and 275 GW by 2027. At the United Nations' Climate Summit in New York on 23 September 2019, the Prime Minister of India announced a new target of 450 GW of renewable electricity capacity, without specifying a date.

At the end of November 2019 grid-connected renewable electricity capacity reached 84 GW, with 32 GW coming from solar photovoltaic (PV), around 37 GW from onshore wind and the remainder from small hydro. Solar PV has been on a rapid rise in recent years.

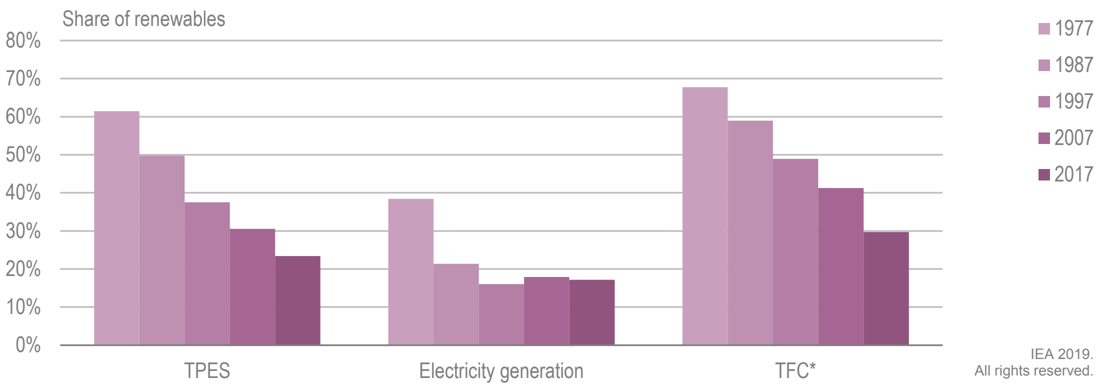
To increase investment in renewable electricity in a cost-effective way, India has introduced national competitive auctions for wind and solar PV. Lessons have been learned following the abrupt change in the renewables support scheme from feed-in-tariffs to centrally run reverse auctions. Current auction volumes show that wind power has developed at a much slower pace than solar PV. The auctions complement other policy measures at state level, such as Renewable Purchase Obligations, and at a local level, such as further support for rooftop PV installations. To ensure continuous progress in the growth of renewables, auction design, grid connections and the financial health of the power distribution companies (DISCOMs) are critical elements for reform.

Modern renewable energy is not only used in electricity generation – the potential is also great for heating, cooling and transport. India needs a holistic strategy for renewable energy to tap into this potential and to make sure that market development can be beneficial for sustainable development more generally, including local air and water quality. Potential also exists to scale up the use of bioenergy, including energy-from-waste (EfW), which requires robust sustainability governance.

Supply and demand trends

Renewable energy in India has long been dominated by traditional use of biomass in the residential sector. However, in recent years the country has rapidly expanded its use of renewable power sources. This has kept the share of renewables in electricity generation stable at around 16% over the last decade amid strongly increasing electricity consumption, although the share of fossil fuels in total primary energy supply (TPES) and total final consumption (TFC) has significantly increased since the 1970s (Figure 5.1).

Figure 5.1 Share of renewable energy in TPES, electricity and TFC, 1977-2017



The share of renewables in India's energy system has fallen for decades, except in electricity generation where the rapid growth in renewables has kept up with the increase in capacity.

*Includes direct use of renewable energy sources and indirect use through electricity consumption.

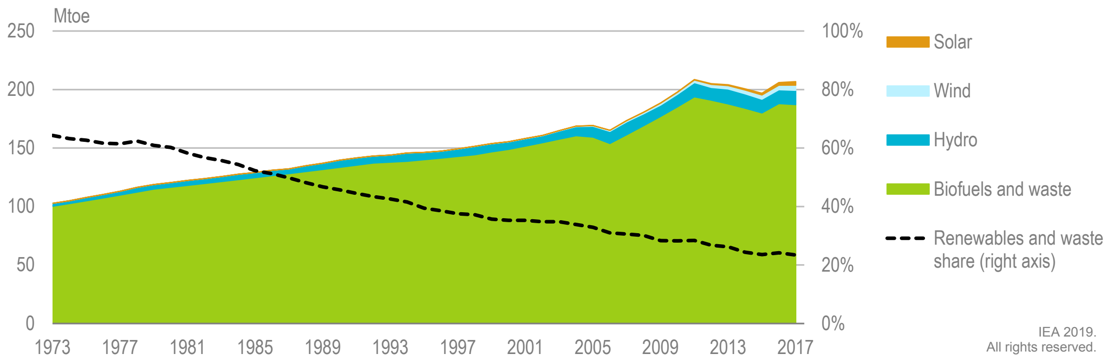
Notes: Bioenergy data are estimated by the IEA.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Renewable energy in TPES

Traditional use of biomass for heating and cooking in households is by far the largest source of renewable energy in India. Bioenergy consumption has increased steadily with population growth for decades, albeit at a slower rate than overall energy supply. Thus, the share of renewables in TPES has been declining over time, despite a recent increase in renewable power generation from hydro, wind and solar photovoltaic (PV) (Figure 5.2). In 2017 the total supply of renewable energy was around 200 Mtoe, representing 23% of TPES.

Figure 5.2 Renewable energy and waste in TPES, 1973-2017



Bioenergy and waste dominate renewable energy supply in India, but the share of renewables in TPES has dropped.

*Includes primary solid biofuels, liquid biofuels, biogases and renewable municipal waste.

Notes: Bioenergy data are estimated by the IEA.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Electricity from renewable energy

Although traditional use of bioenergy represents the largest supply of renewable energy, the most dynamic development is in the electricity sector, with renewable electricity generation from a range of technologies including hydropower, wind, solar and bioenergy.

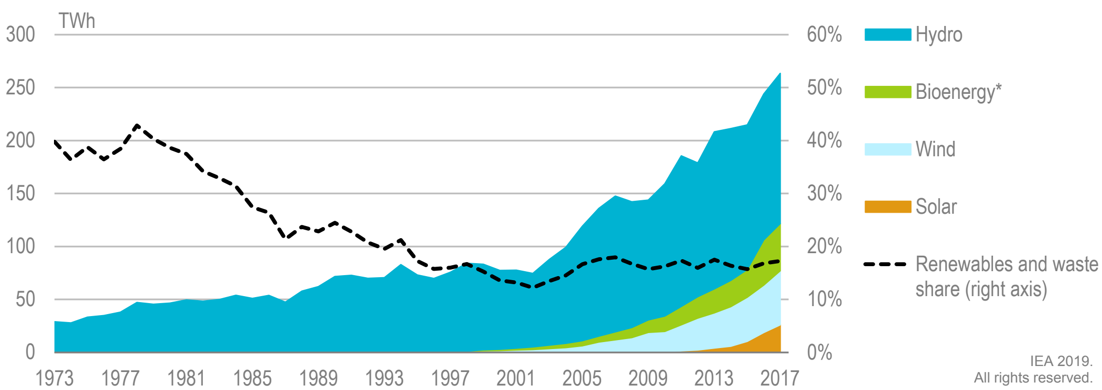
Hydropower has been the dominant source of renewable electricity in India for a long time. In the late 1970s hydropower alone accounted for around 40% of total electricity generation. Although the supply of hydropower has increased steadily, its share of electricity generation has fallen to around 10%. In the last decade very strong growth in electricity from wind, solar PV and bioenergy has maintained the total share of renewables stable around 16-17% (Figure 5.3).

Wind power generation has increased at an average annual growth rate of 14% in the ten years 2007-16, accounting for 3.3% of total electricity generation in 2017. Solar power has only started to grow in the last few years, supported by the 2022 target and auctions for new PV installations. In the five years 2013-17, solar power generation increased by 64% per year on average.

Bioenergy is also increasing in power generation. The principal source is co-generation units using bagasse residues from India's large sugar industry. Using biomass for power generation is a more sustainable use of bioenergy resources than the traditional use in households.

A minor share of electricity comes from EfW projects using urban, industrial and agricultural wastes and residues. EfW can provide energy at the point of demand and support the waste management sector in India. Increasing urbanisation and economic growth present pressing waste management challenges for cities and therefore potential exists for further development of the EfW sector.

Figure 5.3 Renewable energy and waste in electricity generation, 1990-2017



Hydropower is the largest source of renewable electricity, but the greatest growth in recent years has come from wind, solar PV and bioenergy.

*Includes primary solid biofuels, liquid biofuels, biogases and renewable municipal waste.

Notes: Bioenergy data are estimated by the IEA.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Institutions

The dedicated **Ministry of New and Renewable Energy (MNRE)** is in charge of the development of policies for renewables in electricity, transport and heat in India. The MNRE contains the National Institute of Solar Energy and the National Institute of Wind Energy, undertaking activities related to R&D, testing, certification, standardisation, skill development, resource assessment and awareness. The MNRE also covers bioenergy for electricity, including EfW, and biogas. The Indian Renewable Energy Development Agency (IREDA) under the MNRE functions as a non-banking financial institution for providing loans for renewable energy and energy efficiency projects.

Solar Energy Corporation of India (SECI) is responsible for implementing various MNRE subsidy schemes, such as the solar park scheme and the grid-connected solar rooftop scheme. **SSS-NIRE** is an autonomous institution of the MNRE, an emerging R&D centre with a mandate to focus on bioenergy and develop innovative technologies in the area of renewables and biofuels.

The **Ministry of Power (MoP)** governs the electricity sector in India, including renewables for power generation. The Minister of Power has also oversight of the MNRE and is in charge of renewable energy. As an agency of MoP, the Central Electricity Authority (CEA) is the main advisor to the MoP and is responsible for the technical co-ordination and supervision of programmes, including drafting the National Electricity Plan. The MoP is also responsible for the Ujwal DISCOM Assurance Yojana (UDAY) programme, which aims to improve the financial health and operational efficiency of India's debt-ridden DISCOMs.

The **Central Electricity Regulatory Commission (CERC)** regulates the tariffs for generation companies and transmission utilities, and grants licences for interstate transmission and trading.

The Ministry of Petroleum and Natural Gas (MoPNG) is the overall co-ordinating ministry for the development of biofuels and implementation of national biofuels policy. The MoPNG manages the marketing and distribution of biofuels, blending levels, pricing and procurement policy, and capacity building. The **Ministry of Science and Technology (Department of Biotechnology and Department of Science and Technology)** has responsibility for innovation and has a strong focus on bioenergy technology research.

Policy and regulation

Electricity

The government has a target to achieve 175 GW of grid-connected renewable electricity by March 2022: 100 GW solar, 60 GW wind, 10 GW biomass and 5 GW of small hydropower. In addition, the MNRE is targeting 1 GW of geothermal capacity by 2022. The 2018 National Electricity Plan sets out ambitions to achieve 275 GW of renewables by 2027, which would increase their share to an estimated 44% of installed capacity and 24% in electricity generation.

Utility-scale renewables

For utility-scale renewables India relies on renewable purchase obligations (RPOs), renewable electricity certificates (RECs), accelerated depreciation of renewable energy assets for commercial and industrial users, and most recently on competitive tenders.

The RPOs require DISCOMs, energy producers and certain consumers to obtain a share of their electricity from renewable sources. Determination of RPO trajectories and monitoring of compliance are carried out by the State Electricity Regulatory Commissions. In June 2018 the RPO requirement was raised from 17% to 22%, with 10.5% from solar, up from 6.75%, and 10.5% from non-solar renewable sources by 2022, up from 10.25%. It will need to be raised for the 450 GW target in the future.

The RECs are used by the obligated entities to meet their RPO requirements. The CERC established voluntary RECs in 2010 and allowed their trading in March 2011 to address the discrepancy between the availability of electricity from renewable sources across the regional markets and the demand from obligated utilities and customers to meet their RPOs under the Electricity Act 2003. The REC programme is enforced by the CERC. However, the REC markets have been insufficient in encouraging large investments because of demand and investment uncertainty in the absence of long-term targets and poor compliance.

The GoI approved a number of measures in March 2019 to promote the hydropower sector in the country, including declaring all hydropower projects as renewable energy projects and providing for hydro purchase obligations (HPOs), similar to RPOs. HPOs will help improve the economic viability of hydropower projects.

The accelerated depreciation tax benefit for renewable energy plant developers was re-established in 2014 after a two-year long gap and was fixed at an 80% level until March 2017. As of 1 April 2017 the benefit was lowered to 40%. Users of renewable energy can depreciate their investment in a renewable energy plant at a much higher rate than general fixed assets and can claim tax benefits on the value depreciated in a given year. The tax benefit is available for several renewable technologies, including flat-plate solar collectors, concentrating and pipe-type solar collectors, solar power generating systems, windmills and related devices, biogas plant and engines, electrically operated vehicles including battery-powered or fuel cell-powered vehicles, and agricultural and municipal waste conversion devices.

In order to reach the 2022 target, the government launched competitive auctions for solar PV (2010) and wind (2017) with long-term power purchase agreements containing fixed-price contracts. The MNRE announced it would tender 25-30 GW annually until end of 2021 to reach the solar PV target of 100 GW by 2022 (in 2019, India had 32.5 GW of installed solar capacity).

SECI implements large-scale central auctions for solar parks and has awarded contracts for 47 parks with over 25 GW of combined capacity. The main idea of solar parks is to provide projects with a "plug-and-play" interface such that developers can focus on other aspects of project development and reduce project risks. The MNRE has recently amended guidelines for competitive bidding with provisions to reduce offtake risk, address revenue shortfall from curtailment and minimise delays related to land acquisition. However, land acquisition, grid integration and connection concerns have caused delays in the SECI auctions.

In this context, February 2017 marked an important step for ensuring the financial viability of off-takers. SECI joined the tripartite agreement between the GoI, state governments and the Reserve Bank of India (RBI). SECI is the counterpart for central auctions of variable renewables and then sells this electricity to DISCOMs via power supply agreements. The tripartite agreement ensures that SECI is compensated for any payment delays from DISCOMs via a mechanism guaranteed by the RBI, thus making it a low-risk off-taker. The National Thermal Power Corporation (NTPC), which also holds auctions for renewables, is also party to this agreement and thus is a viable off-taker.

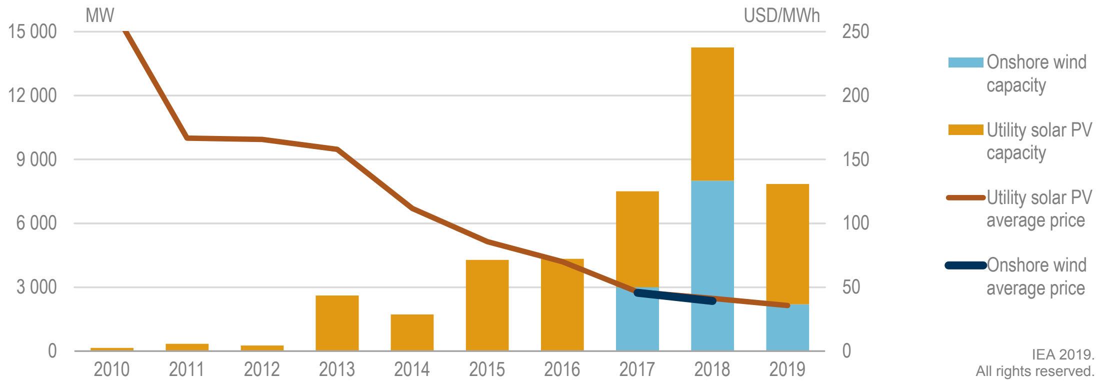
The reverse auctions, managed by SECI, have led to the accelerated deployment of solar PV at utility scale, while wind auction volumes doubled from 2017 to 2018 (see Figure 5.4). Onshore wind and solar PV auction prices are well aligned and have come down to the lowest levels discovered in India to date – in 2019 around USD - with some bids down to USD 26/MWh for solar and USD 24-28/MWh for wind (see Figure 5.4).

Renewable generators are granted must-run status under the Indian Electricity Grid Code 2010 and various state grid codes and regulations under the Electricity Act 2013. Curtailment is only allowed for reasons of grid security by the State Load Dispatch Centres (not commercial curtailment) and compensation rules are in place.

At the same time, renewable projects that are commissioned through competitive auctions and connect until 2022 directly to the interstate transmission power network are exempt from transmission charges for 25 years. India is investing in transmission across the country, notably through its Green Energy Corridors.

The MNRE also adopted a policy for repowering of onshore wind installations in 2018 (MNRE, 2018b). No financial support is given by the government with the exception of tax benefits (accelerated depreciation).

Figure 5.4 Auction volumes and prices, 2010-19



Note: The right axis reflects prices in USD/MWh achieved in the auctions.
Source: IEA (2019b), *Renewables 2019*.

Rooftop solar PV

For residential and commercial solar PV applications, the GoI has set an ambitious target of 40 GW of rooftop solar by 2022 within the 100 GW solar target. The MNRE has adopted guidelines for the implementation of Phase II of its Grid-Connected Rooftop Solar Programme.

The target is supported by RPOs, rooftop auctions and programmes that facilitate the deployment of rooftop solar PV on government buildings across states. The MNRE has several policies to incentivise and facilitate rooftop installations: a) providing central financial assistance for residential, institutional, social and government buildings; b) advising states to implement net/gross metering regulations and tariff orders; c) providing a model memorandum of understanding, power purchase agreement (PPA) and CAPEX agreement for rooftop projects in the government sector; and d) appointing experts to support public-sector undertakings in the implementation of rooftop projects in ministries and departments.

In February 2019 the Cabinet Committee on Economic Affairs (CCEA) approved financial support totalling USD 6.5 billion by 2022 to promote the use of solar among farmers.

Solar deployment is picking up given India's high electricity retail prices with net metering programmes in 28 states with various tariff structures.

Offshore wind

The GoI estimates the potential of offshore wind to be in the region of 10-20 GW. A good alternative to onshore wind, offshore wind, however, has yet to be adopted in India. An initial tender of 1 GW is expected to be held and a white paper is being developed in collaboration with the European Union to identify bottlenecks in the supply chain and industry infrastructure, as India does not have a large-scale offshore turbine industry.

Off-grid solar PV

Various schemes are available at both national and state level to support the uptake of off-grid electrification, mainly through solar technologies. In 2015 the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) scheme was launched to support the adoption of decentralised distributed electricity in rural India via off-grid installations, mainly mini-grids.

In 2017 the Off-Grid and Decentralised Solar PV Programme was put in place to facilitate uptake of various solar PV applications for lighting and water pumping in rural areas by providing financial means to the implementing agencies. The programme was extended until the end of the 2020 financial year.

In December 2018 the Atal Jyoti Yojana (AJAY) Phase II programme was initiated to finance the installation of over 3 million solar street lights in selected regions.

Initiated by the GoI in February 2019 (and followed by guidelines in July 2019), the KUSUM scheme will support farmers to replace existing diesel pumps with solar PV pumps (with both on-grid and off-grid features). The scheme will allow farmers to become prosumers and sell power to the DISCOMs at a predetermined price. The scheme aims to add solar and other renewable capacity of 28 GW by 2022. It has three main components: a) financing of 10 GW of renewable energy plants, each up to 2 MW capacity; b) offering 1.75 million standalone solar agriculture pumps, central government to provide 30% subsidy and state government to provide 30% subsidy; and c) converting 1 million grid-connected agriculture pumps to solar powered operation with central government and state government providing 30% subsidy each.

India also supports off-grid EfW uptake by providing capital subsidies for the purchase and installation of biomass gasifiers in rural areas.

Bioenergy and waste

India is close to meeting its 2022 target for 10 GW of bioenergy capacity. The principal contributor is the use of bagasse in sugar mill co-generation plants. The Scheme to Support Promotion of Biomass-Based Co-generation in Sugar Mills and Other Industries offers central financial assistance in the form of a capital subsidy per additional MW of capacity delivered by investment in more efficient co-generation technology and runs until 2020. There is scope to increase electricity generation from sugar mills when they are upgraded to more efficient co-generation systems.

India has also introduced a policy to instigate low-level biomass co-firing (5-10%) in appropriate power generation facilities. This will serve as a means of offsetting coal use while also valorising agricultural residues that may alternatively have been burned in the field, degrading air quality.

India's 2016 waste management rules provide the basis for stimulating greater exploitation of EfW. For example, the rules stipulate that states should: procure all electricity generated from EfW projects; support the promotion of using waste in industry when it is available within a 100-kilometre radius; encourage waste segregation and require that non-recyclable waste of high calorific value be used for energy.

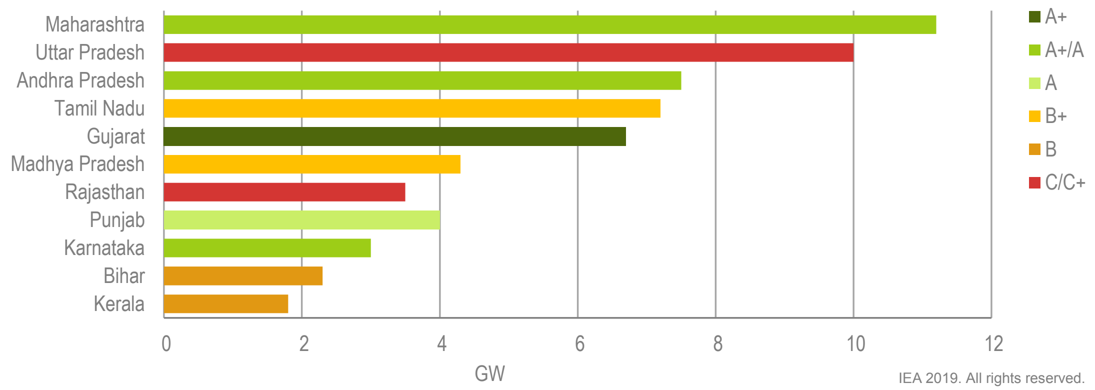
Barriers to investment in renewable energy projects

Besides permitting and network expansion delays, the key barriers to investment in renewable energy projects in India are the small transaction size for distributed energy projects, the credit rating of the off-taker, the absence of clear business models for rooftop solar and the disaggregated nature of the market.

India's DISCOMs are at the forefront of investing in solar PV. However, their financial viability as off-taker has come under pressure because of poor payment discipline, high commercial and technical electricity losses and consequent financial losses, cross-subsidised electricity prices that do not cover costs, and a lack of metering and billing. Many states have also carried out competitive auctions, with some cancelling the PPAs due to a lack of financial viability of the sector, as PPAs offer fixed-price contracts.

In 2015 the GoI adopted the UDAY scheme, which seeks to alleviate high debt and interest cost burdens on DISCOMs, and has improved their financial health since its introduction. However, its impact varies considerably across states. As can be derived from Figure 5.5, at least 40% of capacity additions needed to meet India's 2022 solar PV target are allocated to states with DISCOMS that have below-average to very low operational financial performance, according to government ratings (B-C grade).

Figure 5.5 Solar PV capacity needed to reach 2022 targets and financial health of DISCOMs by state, July 2018



Source: IEA (2018a), *Renewables 2018*.

Financing decentralised projects, such as solar irrigation pumps, rooftop solar and mini-grids, is often more difficult than funding utility-scale projects despite the very large markets for these products. Local banks have limited capacity and tend to prefer the larger transaction sizes associated with utility-scale projects. Moreover, there is a lack of frameworks for evaluating the creditworthiness of smaller companies and consumers.

Priority sector lending by the RBI and others now includes renewable energy projects and grid-connected solar rooftop systems (MNRE, 2018a). The Department of Financial Services advised all public-sector banks to provide loans for grid-connected rooftop solar systems as a home loan or a home improvement loan, and the Department of Expenditure reduced the guarantee fee from 1.2% to 0.5% for multilateral loans totalling USD 1.370 billion (these are: World Bank loan of USD 620 million through State Bank of India; Asian Development Bank loan of USD 500 million through Punjab National Bank; and New Development Bank loan of USD 250 million through Canara Bank).

In July 2018 India's Ministry of Finance imposed a so-called safeguard import duty of 25% on solar imports from the People's Republic of China ("China") and Malaysia for two years, to protect domestic producers of solar panels for a period of two years (falling to 20% in 2019 and 15% thereafter). The duty is contested and legal proceedings are ongoing in the Supreme Court. This uncertainty is a risk for developers and has stalled some projects. However, recent auction results, if commissioned, show a limited impact on projects due to recent cost reductions for Chinese imports.

For tenders carried out by the central government, the payment security mechanism provided by the SECI was seen as supportive, but there are some concerns over its operation in practice. Moreover, the tripartite agreement between the RBI, central government and state governments may serve as the *de facto* guarantee mechanism for payment by DISCOMs. However, these frameworks for mitigating off-taker risk do not apply to PPAs struck directly with states. In 2019, the GoI requires DISCOMs to provide for a letter of credit before scheduling power supplies.

The risks facing renewable investments generally fall into two categories: project development risks; and operational risks (Table 5.1). These pose challenges to investments where they reduce the availability of financing, elevate the cost of capital or delay project development.

Similar to trends in other emerging economies, the average size of projects sanctioned under renewable tenders for utility-scale solar PV has grown over threefold since 2014 and almost fivefold for onshore wind, with a boost in 2017 from the introduction of wind auctions. However, persistent development risks remain, which delay project commissioning, centred on problems of land acquisition, rights of way, grid connection and availability of local infrastructure, including for evacuation of power. There is lack of clarity over land titles, with outdated records and fragmented landholdings, particularly in Jharkhand, Uttar Pradesh, Bihar and Odisha (IEA, 2018b). Wind power tenders have been designed to sell power through the interstate transmission system, rather through a specific state transmission utility. As a result, wind projects are generally being sited in relatively resource-rich states, such as Gujarat and Rajasthan.

The Green Energy Corridors project started in 2013 to establish dedicated grid infrastructure to connect resource-rich states and enable intra- and interstate transmission to load centres. A second project phase is now in preparation, with the integration of renewable energy management centres (see chapters on electricity and system integration). Continued investment in transmission networks remains crucial to enhance trade in electricity and balancing services across states. Transparent and timely communication to developers about the status of major transmission projects is important for managing integration risks, as is continued progress in transmission investment, such as through the Green Energy Corridors programme. The government's recent policy to facilitate solar–wind hybrid plants, which can include battery storage, may help to better optimise transmission infrastructure and balancing the needs of variable renewables (see Chapter 8 on system integration of renewables).

The waiver of interstate transmission charges for wind and solar energy projects that directly connect to these lines (adopted in 2016 and applicable to all projects commissioned before the renewables target deadline of 2022) further facilitates infrastructure access.

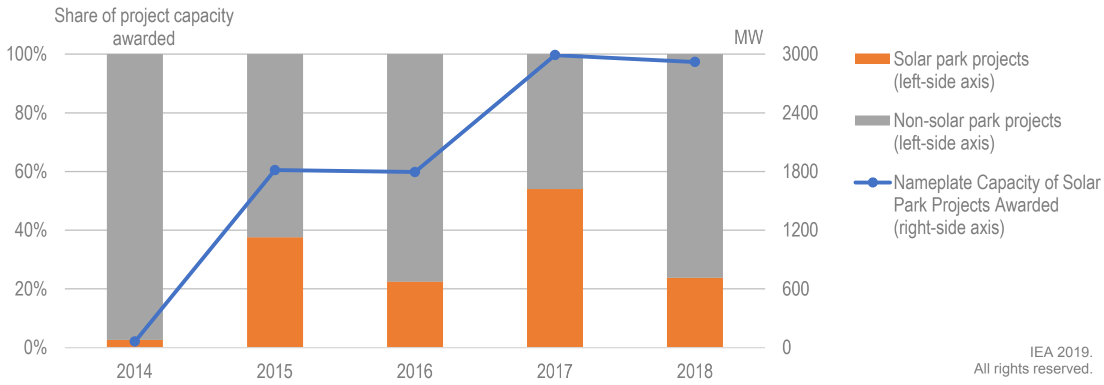
Under its solar parks scheme, the central government provides financial support to the states to facilitate bringing parcels of land and supporting infrastructure together in a simplified process. Around half of utility-scale solar PV projects sanctioned in 2017 were designed to be developed in solar parks (Figure 5.6). Recognising the risk management and efficiency benefits of solar parks, the central government approved in 2017 an upward revision to the targeted solar park capacity, from over 20 GW to 40 GW by 2020. While nearly 40 solar parks, covering potentially 22 GW of capacity, have already been sanctioned under the scheme, not all of these are operational yet.

Table 5.1 Risks and risk management for renewable investment in India

Risk	Description	Potential managing mechanisms
Power prices	States expect low power prices from renewables, with some setting ceilings near INR 3/kWh, but developers face uncertainty over technology prices and duties.	Portfolio approach to project development supplemented by contracts with equipment suppliers.
Bankability of PPAs	Delays in the signing of PPAs or cancellations; higher-than-expected project costs relative to a fixed-price contract.	More rapid timelines and better standardisation for PPAs; project structuring to exploit economies of scale and factor in contingencies.
Contract renegotiation	States may seek to renegotiate power purchase contracts after seeing lower prices elsewhere.	Enforcement of sanctity of contracts by regulators.
Power purchase	Delays in the payment of power purchase and curtailment by off-takers.	Improving the financial viability of state DISCOMs and expanding options for third-party off-takers; project structuring with financial guarantees.
Transmission infrastructure	Insufficient exchange of electricity and system services across states, which can hamper balancing.	Communicating to developers the status of major transmission projects in a transparent and regular manner; hybridisation of wind and solar plants; continued progress in transmission investment, such as through the Green Energy Corridors programme.
Land acquisition	Lack of clarity over land titles, with outdated records and fragmented landholdings; rights-of-way concerns.	Solar parks.
Evacuation infrastructure	Availability of local grid connection and network is uncertain; no secondary market for connectivity rights.	Solar parks; timely planning for grid infrastructure; penalty mechanisms to protect generators in case of transmission non-availability.
Financing for small-scale projects	Lack of frameworks for evaluating creditworthiness of small companies; limited capacity of local banks, which prefer larger transactions.	Lines of credit from public financial institutions for on-lending; credit appraisal methods for small consumers and capacity building for local banks; state-supported aggregation mechanisms.
Transparency of asset-level risks	Lack of ongoing metrics for lenders to assess susceptibility of assets to become stressed.	Developing dynamic asset-level risk assessment for projects.

Source: IEA (2018b), *World Energy Investment Report 2018*.

Figure 5.6 Role of solar parks in utility-scale solar PV project development



Solar parks are playing a larger role in sanctioned utility-scale solar PV projects, but their potential is not fully exploited, in part due to their relatively high prices and government land acquisition challenges.

Note: Solar parks are defined as those sanctioned under the MNRE's Solar Park Scheme. Projects with multiple phases are treated as single projects when awarded in the same year and sharing a common developer.
Source: IEA (2018b), *World Energy Investment 2018*.

Transport

India has a long standing ethanol blending programme. Today around 2 billion litres of ethanol are consumed across India and in several union territories, where the programme has been implemented by the oil marketing companies (OMCs).

The mandated level of 5% ethanol blending has not been met to date, although 2017/18 saw a record high blending rate of over 4% achieved. Consumption has fallen well short of more ambitious 10% blending targets for ethanol-producing states, and aspirational 20% blending goals. In the past there was no formal national mandate for biodiesel blending, but several more localised 5% blending initiatives have been undertaken. Fuel distribution is largely in the hands of public-sector national OMCs. India's biodiesel production is still at an early stage of development, allowing blends of up to 5%. There are around 3 400 outlets in seven states that offer B5 diesel.

In 2018 the MoPNG introduced a new biofuels policy covering both conventional and advanced biofuels (MoPNG, 2018).[1] This superseded the previous biofuels policy of 2008. The new policy proposes an indicative target of 20% ethanol blending in gasoline and 5% biodiesel blending in diesel by 2030 among other key pillars, as shown in Figure 5.7. The new national biofuels policy widens the range of feedstocks allowed to be used as a base for ethanol – expanding from only the molasses produced by India's large sugar industry, to include sugar cane juice, sugar and starch crops (e.g. corn and cassava) in years when there is a projected oversupply, and damaged food grains. This is anticipated to support production growth. The new policy links ethanol and sugar cane pricing, and establishes differential prices for ethanol depending on production feedstock. Public-sector financial support for greenfield and brownfield investments to increase ethanol production capacity has also been introduced.

[1] The IEA considers advanced biofuels as sustainable fuels produced from non-food crop feedstocks, which are capable of significantly reducing lifecycle GHG emissions compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts.

Figure 5.7 National biofuels policy, 2018

Indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel by 2030	Central Government Funding Scheme for 2G ethanol bio-refineries, tax incentives and higher purchase price for 2G	Biofuel categorisation: • Basic biofuels (1G bioethanol/biodiesel) • Advanced biofuels (2G ethanol, drop-in fuels, algae-based 3G)	Increase the scope of raw material for ethanol procurement (B-molasses, sugarcane juice, surplus food grains)
National Biomass Repository based on appraisals conducted across India	Encourage biodiesel production from used cooking oil, edible oil seeds, short gestation crops. Develop supply chain mechanisms.	Foster RD&D in biofuel feedstock development	National Biofuels Coordination Committee (NBCC) under MoPNG

Notes: 1G = first generation; 2G = second generation; 3G = third generation.

The new biofuels policy outlines several measures to support advanced biofuel production, including additional tax incentives, a higher purchase price than for conventional biofuels and investment support. Advanced biofuels will benefit from more favourable administratively set purchase prices. India's ethanol production, which is by far the principal biofuel used, offers greenhouse gas emission reductions. It is produced from molasses residue feedstocks, a by-product from the sugar industry.

The feedstock extension in the new biofuels policy takes account of food production, for example only allowing damaged grains. No sustainability concerns arise from this biofuels policy, except for water demand in some areas. India is at the forefront of developing an advanced biofuel industry and in 2018 accounted for around one-fifth of announced and under-development novel advanced biofuels projects globally, according to the IEA (2018b). OMCs are now developing 2G ethanol and plan to invest in 12 bio-refineries in 11 states with a total investment volume of USD 120 million. The GoI aims to provide incentives for farmers to bring their waste to the refineries.

Industry

The National Biogas and Manure Management Programme set a target for 65 and 180 biogas plants in 2017/18. A programme to promote off-grid and decentralised concentrated solar thermal (CST) technologies for community cooking, process heat and space heating and cooling applications in industrial, institutional and commercial establishments was extended in February 2018 to run until 2020.

At the end of 2018 around 300 MW of EfW capacity had been installed, and the country's largest plant (24 MW) was commissioned in New Delhi in 2017. The GoI promotes the use of urban, industrial and agricultural waste and residues with a programme providing financial assistance in the form of capital subsidy and grants, with a target of 57 MW equivalent capacity for the period 2017/18 to 2019/20.

The MNRE has partnered with the United Nations Development Programme to promote clean energy use for small businesses and industries under the Access to Clean Energy for Rural Productive Uses programme. It aims to enhance the use of reliable and affordable renewable energy for rural productive uses, providing livelihoods in areas in the states of Assam, Madhya Pradesh and Odisha. India is also providing capital grants for solar thermal applications. The programme was recently extended until 2020 and the subsidy is available for a variety of CST applications, such as community cooking, solar process heat and solar cooling.

India is the second-largest global sugar producer. In the sugar industry (which also produces ethanol for fuel and industrial purposes), bioenergy meets a significant portion of energy demand because sugar cane bagasse is used to generate process heat and electricity for on-site use and export.

India is also the second-largest cement producer globally, with output on an upward trend. The thermal energy required to produce clinker, which is used as a binder in cement products, accounts for most of the total energy used in cement production. This thermal energy is typically produced from fossil fuels, mainly coal. Lower-carbon biomass and waste ("alternative fuels") can substitute for fossil fuels in cement kilns, lowering CO_2 emissions. The potential for greater use of alternative fuels, particularly municipal solid waste, is strong in India. The country's Nationally Appropriate Mitigation Action (NAMA) for waste involves using refuse-derived fuel from urban areas within a specified distance from cement plants, and it anticipates that alternative fuels could generate almost 19% of the cement industry's thermal energy demand by 2030. India's waste management rules also promote the use of waste in industry when it is available within a 100-kilometre radius.

Moreover, a large proportion of steelmaking in India is via direct reduction of iron, which could be a viable application for direct or indirect electrification (renewables-based hydrogen). Direct electrification is possible via: electromagnetic technologies for heating, hardening and melting; heat pumps and mechanical vapour recompression; and inexpensive resistance heaters in boilers or furnaces (taking advantage of cheap "surplus" power when available). Indirect electrification can be achieved via hydrogen and its derivatives as an intermediate energy vector. Possible applications include using hydrogen to produce ammonia for fertiliser production or for use in refineries. Further analysis on the commercial viability of these options is needed to assess the market potential.

Assessment

India has emerged as a global leader in renewable energy, notably in solar power. By end of November 2019 grid-connected renewable electricity capacity had reached 84 GW, including 32.5 GW from solar PV and around 37 GW from onshore wind as well as small hydro.

The GoI adopted an ambitious target of 175 GW renewable electricity capacity by 2022; the target is sub-divided into 60 GW utility-scale solar PV, 40 GW rooftop solar, 60 GW wind power, 10 GW bioenergy and 5 GW small hydro. In 2019, the Prime Minister of India,

Shri Narendra Modi announced a new target of 450 GW of renewable energy capacity. Such a medium-term target can help guide further deployment and auction trajectories over time.

The target has spurred unprecedented growth in solar PV and wind in the country and has gone hand in hand with increased international engagement, including the establishment of the International Solar Alliance. In addition, modern bioenergy use in power generation and industry has been expanding rapidly.

India has put in place a number of important policies that have underpinned recent strong expansion of renewables. However, it will need to further strengthen policy action and accelerate policy implementation to address a number of barriers that still hamper renewables deployment. Among the main investment barriers and risks to renewable electricity growth in India are the financial health of DISCOMs, weak transmission and distribution grid infrastructure and difficulties in permitting and land acquisition.

According to IEA data, bioenergy and waste is the largest source of renewable energy in India's primary energy supply (21% of TPES, the third-largest energy source in India). However, more than two-thirds of India's bioenergy consumption comes from traditional use of biomass in the residential sector resulting in negative environmental and health impacts. The GoI has introduced policies promoting modern and clean use of bioenergy in households, as well as the replacement of the traditional use of biomass with alternative cooking and heating fuels, both renewable (solar cooking) and non-renewable (such as LPG).

Electricity

Historically, large hydropower has been the dominant source of renewable capacity and is still the largest contributor to renewable electricity generation (46 GW), with a large untapped potential. However, other technologies are quickly catching up. The GoI has set out longer-term targets of 275 GW by 2027 and 450 GW of renewable energy capacity thereafter, which would translate into a share of 40% of total installed capacity.

The 175 GW renewable electricity target for 2022 has given an increased impetus to existing policies and measures, while also stimulating the adoption of new instruments, notably centrally run auctions for solar and onshore wind. These aim to address a number of issues including: a) ensuring demand for renewable electricity from financially viable off-takers; b) facilitating land acquisition for projects and timely grid connection; c) reducing policy uncertainty; and d) ensuring sufficient power system flexibility, including robust grid infrastructure, battery storage and smart grids (see Chapter 8 on system integration of renewables).

However, the targets cannot be achieved by central auctions alone. State auctions by DISCOMs are also relevant. Improving the financial viability of DISCOMs (see Chapter 7 on electricity) is thus a key measure for achieving the renewable energy target. At the same time, auctions should better reflect the location and value of power to the system, not only the price offered.

One mechanism that can contribute to ensuring sufficient demand for renewable energy at a state level is the RPO. RECs are used by the obligated entities to meet their specified RPO. The State Electricity Regulatory Commissions determine RPO trajectories and monitor for compliance.

In 2018 the GoI announced an increased ambition of 227 GW renewable capacity by 2022. In June 2018 it raised the quota for RPOs from 17% to 21% for 2022/23, with a view to increasing the share of renewables in the mix of India's large power consumers in line with the increased ambition. While the relevance of the RPO has somewhat diminished with the increased cost-competitiveness of renewables, ensuring ambitious state-level targets and enforcing compliance would provide increased visibility and certainty for the renewables industry.

Transmission grid infrastructure has been expanded, including through the Green Energy Corridors programme. Good progress has been made since the launch of this initiative thanks to the financial support of the central government to the states. However, with the discontinuation of the Clean Energy Fund, further extension of interstate transmission grid infrastructure is at a risk. Much of the deployment does not take place at interstate level, but at the intrastate transmission level. Better transmission planning is critical for the Indian power system and the successful integration of renewables in the system (see dedicated Chapter 8 on system integration).

Solar parks have been designed as an instrument to overcome land acquisition and connectivity issues. They have experienced some delays compared to original schedules, but their further smooth implementation will be a crucial tool for ensuring continued solar PV deployment. Because of lower availability of high-resource land, the solar park concept cannot be replicated readily for wind power plants and land acquisition remains an important challenge for onshore wind.

Contracting for new onshore wind projects moved from administratively set price incentives (generation-based incentive, feed-in tariff) to an auction system in 2014/15. While such a shift is in line with global policy trends, a delay in auctions and issues with auction design led to a hiatus in capacity deployment. Wind additions peaked in 2016/17 as developers rushed to connect projects before the expiry of the generation-based incentive, but then dropped sharply the year after. This policy transition has been challenging in particular for the domestic wind manufacturing industry, which had planned for continued uninterrupted deployment streams. The design and timing of auctions are among the major challenges for maintaining progress. Publishing trajectories for the different time horizons of renewables targets would support the better planning of auctions and transmission, land acquisition and connection needs.

The July 2019 bidding guidelines have addressed some of the issues, notably by increasing the rate of auctions, relaxing the deadlines for land acquisition and easing penalties, and assessing future increases in the ceiling tariffs for auctions.

Most recently, deployment has also been slowing for large-scale solar PV. In 2018 the introduction of duty of 25% on imported PV panels from China and Malaysia led to uncertainty in the solar PV sector regarding actual equipment costs for developers. Another recent challenge has been the depreciation of the Indian rupee vis-à-vis the US dollar. This introduces foreign exchange risk because renewable energy PPAs are in Indian rupees. The resulting challenges for project financing could be further exacerbated by a global trend towards rising interest rates.

In 2018 an unprecedented number of auctions for new renewables capacity were undertaken, predominantly for solar power. While this is in line with the requirements of reaching the 2022 target, *ad hoc* announcements and very large tendering volumes can bring challenges for successful contracting of capacity. There is also a trade-off between the desire to develop the domestic manufacturing industry and moving quickly. For example, the 10 GW SECI tender linked with 3 GW of annual manufacturing capacity had to be postponed and reduced in size several times due to low developer interest.

Providing longer-term information on planned auction volumes and adhering to such schedules will be an important measure to support market development. It is welcome that the MNRE has proposed a monthly schedule to co-ordinate activities between SECI, NTPC and public-sector undertakings and state agencies, so as to avoid several auctions at the same time.

The recent price drop for panels has made solar PV technology more attractive for some DISCOMs, but has also increased the appetite for states to renegotiate or cancel contracts for projects previously awarded at much higher prices. In July 2019 the government of Andra Pradesh decided to unilaterally cancel the PPAs that were in the pipeline.

Deployment of distributed solar PV is also facing challenges and so far only 2.14 GW of small-scale solar PV has been installed. Lack of commercial interest by DISCOMs, the relatively small average system size, especially in the residential sector, combined with often low-quality installations are seen as the main reasons for the slow deployment. Nevertheless, good progress has been made in some states, where state nodal agencies and DISCOMs have started to aggregate demand through unification of state tenders for subsidised rooftop plants to standardise quality and cost per installed kilowatt.

Net-metering policies are being implemented in 28 states and could enable faster expansion of distributed solar PV, but tariff reform and the presence of aggregators could improve the approvals process and system design, especially for residential applications where retail tariffs are subsidised significantly.

The political determination behind, and continued improvement of, the policy environment for renewable electricity are highly commendable. Expanding ambition to technologies beyond wind and solar in electricity, as well as taking a more holistic approach across sectors, could further enhance the contribution of renewable electricity to meeting India's energy policy objectives.

Transport

The development of transport biofuels can support various GoI ambitions and programmes, such as: developing technology, skills and employment under the Make in India programme; increasing farmers' income; reducing energy imports and therefore meeting the goal to reduce crude oil imports by 10% by 2022; and supporting waste to wealth creation.

India has historically struggled to meet its 5% ethanol blending mandate and biodiesel is at an early stage of development, as there is no formal mandate. Under the new 2018 biofuels policy the long-term drivers for expansion of the fuel ethanol industry are strong. Production capacity is set to increase as a result of the large number of applications for new subsidised government loans, which combined with the expansion of the permitted feedstock base for production should see ethanol output grow.

Increased fuel ethanol production would support the financial health of sugar mills while also displacing a higher share of gasoline demand – which is anticipated to grow at approaching 10% per year over the next five years – with a lower-carbon alternative. Therefore, using domestically produced ethanol is viewed as a means to offset oil demand, in line with the aim of reducing crude oil imports by 10% by 2022.

OMC's ethanol procurement processes are likely to need streamlining, and interstate logistical barriers (e.g. taxation) and constrained storage capacity at refineries will need to be dealt with to ensure the 5% mandate can be met and production can move towards the more ambitious 20% blending target within the new biofuels policy. Besides ethanol, biogas, compressed biogas and methanol are considered to have strong growth potential.

Scaling up biodiesel production and consumption remains challenging, with securing sufficient access to sustainable feedstock a key priority. Growth will require increased plant capacity, feedstock supply mobilisation and policies to facilitate demand. To ramp up production, the collection of waste residue feedstock will be critical. The production of biodiesel and hydrotreated vegetable oil from used cooking oil feedstock offers promise. Aside from offering significant CO_2 emissions reduction compared to fossil diesel, such fuels can also lower air pollutant emissions. Enforcing regulations for the reuse of cooking oil to avoid negative health impacts could also spur a framework for collection and foster its use to produce biodiesel or hydrotreated vegetable oil.

India's support for the emerging advanced biofuels industry is commendable. Advanced biofuel production in India has the long-term potential to support energy security due to the high availability of agricultural residues. Finding alternative uses for such residues is important to limit in-field burning, which damages air quality. However, the development of India's advanced biofuels industry faces several challenges. These relate to technology development and feedstock logistics such as the collection of waste and residues.

As a founding member of Mission Innovation (MI), India co-leads the Sustainable Biofuels Challenge. The Ministry of Science and Technology (Department for Biotechnology) is co-ordinating the MI programme as key nodal agency. It facilitates national efforts in collaboration with relevant ministries, notably the Ministry of Road Transport and Highways, the MoPNG and the MNRE.

Substantial expertise in advanced biofuels policies is available at international level, from Brazil, the United States and Europe, and the IEA can see significant benefits for India in working through the Biofuture Platform, for which the IEA is the facilitator.

EfW

Despite pressing waste management challenges from urbanisation, population and economic growth trends, EfW activity (in the form of municipal solid waste plants) is very low. Over the longer term, the robust implementation of the 2016 waste management rules should spur uptake.

The use of EfW plants with controlled high-temperature combustion and pollution control technology is a superior solution to landfills, as it can generate electricity for cooling or heating purposes through combined heat/cooling and power generation. This reduces uncontrolled burning, which often happens when waste collection and disposal are inadequate, with negative impacts on air quality. The municipalities need to undertake integrated waste management planning to maximise the reuse and recycling of materials, ensure sufficient collection and source-segregation infrastructure and application of the best pollution control technologies at EfW plants. Factors favouring further EfW deployment include the availability of collection fees, tax incentives and financial de-risking measures. Conversely, low rates of processing and treating collected municipal solid waste hinder sector expansion.

Industry

Many sugar mill co-generation systems in India operate at relatively low efficiency because the low-pressure backpressure steam turbines commonly used are designed to produce steam at the pressure required for on-site processes. The level of electricity generation in these systems is not optimised, however, and consequently the full energy potential of bagasse resources is not exploited. Transitioning to higher-pressure co-generation systems is therefore a key way to increase surplus energy production. Replacing backpressure steam turbines with condensing extraction steam cycle turbines (CEST) maximises surplus electricity and provides an additional revenue stream for mills.

Installing higher-efficiency co-generation plants and using more sugar cane straw could generate considerably more surplus bioenergy per tonne of sugar cane. Furthermore, using new sugar cane varieties (e.g. “energy cane”) could maximise the volume of bagasse resources available from the same planted area. India has made fiscal support available to encourage sugar mills to invest in upgrading their co-generation systems, which should yield more efficient use of bagasse resources.

Using waste as an energy source for properly designed and operated cement kilns is a good alternative to landfill disposal or incineration. Cement plants can provide valuable waste disposal services, especially where waste management infrastructure is limited. However, uptake relies on the application of stringent waste management regulations.

India has good climate conditions for CST systems, which could substitute fossil fuels for a variety of industrial applications such as space and water heating and cooling, process heat and steam, cooling, water desalination, and hybridisation with bioenergy. Industries showing good potential for implementation of CST include food processing, dairy, paper and pulp, chemicals, textiles, fertilisers, breweries, electroplating, pharmaceuticals and rubber. Recent estimates show industry market potential of 6.5 GW for CST technologies in India out of a total of 13 GW thermal technical potential. The GoI, working with the Global Environment Facility and UNIDO, has adopted a scheme to promote the use of such options (MNRE-GEF-UNIDO, 2017).

Recommendations

The Government of India should:

- ☐ Develop a holistic strategy on renewable energy, encompassing both supply and use, for electricity, heating and cooling as well as transport to fully harness India’s large untapped potential.
- ☐ Adapt the design of competitive auctions by SECI to ensure India can meet the 2022 renewable electricity targets by:
  - > setting out annual procurement trajectories
  - > strengthening pre-qualification criteria
  - > adjusting the price caps to ensure commercial viability of high-quality projects
  - > mitigating all project-related risks.

- Adopt a medium- to long-term target for renewable electricity for the period beyond 2022 to give investors certainty.
- Support further growth of distributed renewable energy – notably the solar PV rooftop market – by strengthening and clarifying incentives to implement business models that offer customers standardised solar PV rooftop systems, based on international and national best practice experience.
- Ensure compliance with RPOs imposed by state regulators.
- Strengthen the financial viability of DISCOMs by ensuring the full implementation of the UDAY scheme.
- Maximise India's significant potential for sustainable bioenergy, comprising implementation of the policy on transport biofuels to scale up conventional and advanced biofuel production while ensuring sustainability criteria are met, realising the potential to scale up bioenergy in the sugar and cement industries, and scaling up EfW, using best practice throughout the supply chain.

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6. Energy technology innovation

Key data

Government clean energy RD&D spending (2018): USD 110.61 million*

Total public energy RD&D spend: USD 652.8 million**

Total public energy RD&D per thousand GDP units: 0.23** (IEA median: 0.33; mean: 0.36)***

Private energy RD&D spend: USD 418 million

*Budget reported as part of Mission Innovation.

**Estimate based on available data for 2017 and 2018.

***Median and mean of 25 IEA member countries for which 2017 data are available.

Overview

India is making significant efforts to accelerate energy technology innovation as a means to achieve national policy goals such as enhancing country-wide energy access, fostering economic growth, containing air pollution and meeting climate targets. In recent years, notable success stories have emerged in India's innovation system.

India's energy research, development and demonstration (RD&D) landscape is dominated by the public sector, specifically the central government, and involves a broad range of ministries and related agencies. The role of private sector actors in technology innovation is expected to become increasingly important looking ahead. Under the "Make in India" initiative, the focus is on public–private collaboration to tap into the RD&D capabilities of private actors and scale up domestic technology development and deployment. In 2018 the International Energy Agency (IEA) estimated India's total government spending on energy RD&D at USD 652.8 million across government.

The IEA estimates suggest that the government budget for energy RD&D in India as a share of gross domestic product (GDP) is below, but not far off, the average of IEA member countries (based on available data). India's innovation-specific policy support and national Missions have been important in driving key energy technology development in recent years, in addition to funding support. Recent years have shown a marked increase in funding, especially as India works to double its spending on clean energy RD&D over five years under Mission Innovation (MI). India has also, more generally, been a leader in MI and other multi-lateral collaborations such as the Technology Collaboration Programme organised by the IEA.

India could benefit from a more strategic approach to energy RD&D in the future, including by: a) further improving inter-ministerial co-ordination to align innovation priorities; b) outlining a long-term energy RD&D roadmap to embed RD&D programmes in broader energy policies and steer innovation towards national goals; and c) strengthening institutional and legal frameworks, including intellectual property regimes. Such an endeavour would benefit from the consistent collection and monitoring of energy RD&D data.

Energy technology RD&D and innovation policies

India's draft National Energy Policy has a dedicated focus on energy technology innovation, acknowledging the central role that energy technology can play in "enhancing supply of energy at affordable prices, and deliver it efficiently and sustainably" (NITI Aayog, 2017). The draft also notes the role of government support in acquiring technologies from abroad, encouraging RD&D for unmet domestic needs, and funding innovation directly in some cases. The draft policy is consistent with the Make in India campaign and parallel efforts to improve energy access through electrification.

In the last decade, India has been conducting RD&D in a wide range of technology areas related to energy supply (e.g. advanced biofuels, wind, solar, hydrogen and coal) and demand (e.g. electric mobility and sustainable buildings). In some instances, sector-specific policy documents lay out government initiatives and embed RD&D activities in broader national policy plans, such as the National Offshore Wind Energy Policy (MNRE, 2015), the National Policy on Biofuels (MoPNG, 2018), and the India Cooling Action Plan (ICAP) (MoEFCC, 2019).

For example, the ICAP seeks to "provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits", and mentions Make in India considerations (i.e. the national agenda). In parallel, the plan identifies cooling "as a thrust area of research under national Science & Technology Programme" with "robust R&D on alternative cooling technologies to provide push to innovation" (i.e. the RD&D agenda). The ICAP process required inputs from multiple stakeholders, including several public bodies, industry, think tanks, academia and RD&D institutions, which also stimulates the innovation ecosystem.

In 2018 India launched the Global Cooling Prize in collaboration with MI and the Rocky Mountain Institute, an impact-oriented technology innovation programme offering USD 3 million for solutions that have at least five times less climate impact than current room air conditioners. The policy rationale is that initiatives that combine policy push and RD&D funding provide incentives for a wider range of technology developers to innovate than budget-constrained RD&D funding alone. The intention is to encourage more creative solutions to pressing national challenges. About 140 teams from 31 countries submitted innovative ideas for the prize; ten finalists will develop prototypes with financing of USD 200 000 in 2020; and the winning cooling technology will be awarded USD 1 million by the end of 2020.

To address specific technology areas, the government has initiated energy-related national missions, building on the National Action Plan on Climate Change (2008) (IEA, 2019a). These missions generally mention RD&D components alongside deployment targets and incentive mechanisms. These include the following:

- National Mission for Enhanced Energy Efficiency (2009) (IEA, 2019b)
- National Solar Mission (2010) (IEA, 2019c)

- National Electric Mobility Mission (2012) (MoHI, 2012)
- National Smart Grid Mission (2015) (MoP, 2015)
- National Mission on Advanced Ultra Super Critical Technology (2017) (MST, 2017a)
- National Mission on Transformative Mobility and Battery Storage (2019).

The last of these was recently launched to accelerate the transition to electro-mobility, following NITI Aayog's recommendations to form a consortium in the battery industry, guide innovation efforts with common technology roadmaps, and co-ordinate RD&D activities on advanced batteries. The success of each of these missions will rest in part on the co-ordination and integration of a multi-stakeholder strategy for technology development or acquisition.

Energy technology RD&D landscape

Public-sector RD&D actors

The RD&D landscape in India has historically been largely occupied by the public sector. Funding for energy RD&D mostly comes from the central government, and is governed by over ten ministries and affiliated departments that fund research either with annual public outlays or through their administrative control of public sector undertakings (PSUs) which perform research.

Key public stakeholders involved in energy RD&D are listed in Table 6.1 below. NITI Aayog, as the government think tank, is also an important player in the innovation landscape. In many instances, RD&D execution is limited to government laboratories, PSUs or certified academic institutions. In some cases, private-sector organisations are invited to apply for government funding, but require eligibility certification. Few awards or grants seek small and medium-sized enterprise (SME) participation.

Table 6.1 India's public sector institutional landscape for energy RD&D

Institution	Description of key activities relevant to energy RD&D
Ministry of Science and Technology (MoST)	MoST is the umbrella government body for public-sector science and technology rules, regulations, policy and research support in India.
Department of Science and Technology (DST)	• DST is the country's nodal department for organising, co-ordinating and promoting innovation activities. Research proposals are solicited under annual calls. • DST's Technology Missions Division has run a Clean Energy Research Initiative since 2009, funding research initiatives in solar energy, energy storage, coal, carbon capture, utilisation and storage (CCUS), building energy efficiency, smart grids and energy systems, hydrogen and fuel cells, among others.
Department of Biotechnology (DBT)	• DBT supports RD&D in bioenergy and advanced biofuels. In accordance with the national biofuels policy, DBT oversees five centres of excellence providing long-term support to scientists, academia, research institutes and PSUs (see Box 6.1). • DBT also issues competitive calls for extramural RD&D (over 150 projects presently supported), awards prizes (e.g. "National Champions" innovation grants) and sponsors capacity building, fellowships and international exchange programmes for Indian researchers. It has established the Biotechnology Industry

Institution	Description of key activities relevant to energy RD&D
	Research Assistance Council (BIRAC), a PSU promoting innovation for start-ups and SMEs, notably through the new Clean Energy International Incubation Centre (CEIIC). • DBT also oversees an MI unit to co-ordinate national efforts in clean energy for MI (see Box 6.2). The MI unit also co-funds research activities linked to the three MI innovation challenges for which India is a co-lead.
Department of Scientific and Industrial Research (DSIR)	• DSIR promotes industrial RD&D in India and hosts the Council of Scientific and Industrial Research (CSIR), a network of nearly 40 government laboratories. • Two CSIR labs, the Central Institute of Mining and Fuel Research, and the Indian Institute of Petroleum, specifically focus on energy. Over 15 others pursue some energy RD&D, mostly in efficiency of fossil fuel use and renewable energy sources.
Department of Atomic Energy (DAE)	• DAE funds nuclear power RD&D, supported by the advisory Board of Research in Nuclear Sciences. DAE oversees two research centres, the Bhabha Atomic Research Centre and the Indira Gandhi Centre for Atomic Research, with RD&D topics including advanced reactors, waste management, fuels and materials. • DAE also grants financial support to extramural RD&D including: basic and applied physics; materials, engineering and metallurgical sciences; systems design; reactor and repository design; and chemical and process engineering.
Ministry of Coal (MoC)	• MoC's PSU, Coal India Limited (CIL), co-ordinates coal-related RD&D through its Central Mine Planning and Design Institute (CMPDI). RD&D focuses on exploration, production, safety and environmental impacts. Other ministries, such as MoST and MoP, focus on mitigating the impacts of coal use (e.g. efficiency, carbon capture). • Recent RD&D performers include the CMPDI itself, CIL coal-producing subsidiaries, Indian academic institutions, a number of Australian government and academic institutions, and in a small number of cases, Indian private-sector industrial partners.
Ministry of Earth Sciences (MoES)	• MoES leads science and technology for ocean resources. It engages with industry, academia and other research organisations to perform RD&D via its laboratory, the National Institute for Ocean Technology (NIOT). • The Ocean Energy and Fresh Water programme funds RD&D in desalination (including a large-scale floating demonstrator in the Lakhshadweep Islands), thermal energy conversion, wave energy and hybrid wind/solar/wave systems. • MoES also sponsors gas hydrate resource assessment activities in the Indian Exclusive Economic Zone in collaboration with several national laboratories. Exploration and production technology development are carried out by NIOT.
Ministry of Heavy Industries (MoHI)	• MoHI supports RD&D in the automotive sector through the Automotive Research Association of India (ARAI). ARAI carries out research in fuel economy, emissions reductions, lightweighting, biomass engines and electric vehicles (EVs), with public-private funding. • MoHI also conducts RD&D through its PSU Bharat Heavy Electricals Limited (BHEL), among the world's largest power plant equipment manufacturers. BHEL oversees 12 specialised research institutes and centres of excellence, collaborates with academia and other research institutes in India and abroad, and each BHEL unit includes an RD&D group. Research areas include: advanced ultra-supercritical technology, advanced boilers and turbines, transmission, solar thermal, materials and robotics. Overall, BHEL spends over 2.5% of its turnover on RD&D: in 2016/17, innovation expenditure reached INR 794 crores (USD 120 million).
Ministry of New and Renewable Energy (MNRE)	• MNRE's RD&D Coordination Division promotes innovation in new and renewable energy. It oversees RD&D programmes, three research centres and two PSUs. • MNRE's Technology Development in New and Renewable Energy Programme supports extramural RD&D in solar (majority of RD&D), wind, bioenergy and small hydro energy, supercritical CO_2 technologies, power electronics and hydrogen and

Institution	Description of key activities relevant to energy RD&D
	fuel cells. MNRE also supports the National Institutes of Solar Energy, Wind Energy, and Bio-energy. • MNRE leads two PSUs, the Solar Energy Corporation of India and the Indian Renewable Energy Deployment Agency, which conduct some degree of energy RD&D but remain mostly focused on deployment.
Ministry of Petroleum and Natural Gas (MoPNG)	• MoPNG conducts RD&D related to the exploration, production, refining, distribution and conservation of petroleum and natural gas products. • On behalf of MoPNG, the Oil Industry Development Board (OIDB) provides grants for oil and gas RD&D to the Directorate General of Hydrocarbons, Centre for High Technology, and Petroleum Conservation Research Association, as well as to academia, national laboratories and research institutes. OIDB reported INR 356.9 crores in RD&D grants in 2016/17. • PSUs under MoPNG engage in many RD&D projects. The Oil and Natural Gas Corporation (ONGC) Energy Centre conducts research into hydrogen, bioenergy, nuclear, geothermal, hydropower, fossil, and solar technologies. ONGC also supports other institutes such as the Gas Hydrate Research and Technology Centre or the Institute of Drilling Technology. ONGC reported spending INR 586 crores on RD&D in 2017/18. • Other PSUs conducting RD&D include Indian Oil (e.g. lubricants, concentrating solar for refineries and synthetic fuels), GAIL (e.g. deep sea, gas transport, coal-to-gas and gas-to-liquids), Hindustan Petroleum (e.g. catalysts and lubricants, membranes and bio-hydrogen), Oil India Limited (e.g. geochemistry, enhanced oil recovery and petroleum biotechnology), Bharat Petroleum (e.g. fuel additives, development of new grades and alternative formulations of lube oil) and Balmer Lawrie (e.g. high-performance, biodegradable grease and lubricant).
Ministry of Power (MoP)	• MoP conducts power sector-related RD&D under the supervision of the Central Electricity Authority, which reviews and approves projects. RD&D is guided by the National Perspective Plan on R&D in the Power Sector (2002), a 15-year plan which identified research needs in eight key areas: thermal, hydro, nuclear, new and renewable energy sources, transmission, distribution, environment, and conservation and energy efficiency. • The Central Power Research Institute, a national laboratory for applied research in electric power engineering, conducts RD&D either in house or with industry, utilities, PSUs, academia and research institutions. The Bureau of Energy Efficiency (BEE) is a statutory body which promotes RD&D in energy efficiency. • The National Thermal Power Corporation (NTPC), India's largest utility, is a PSU under the MoP. The NTPC Energy Technology Research Alliance (NETRA), the company's RD&D unit, focuses on four main technology areas: climate change and environment (e.g. CCUS), waste management (e.g. energy-from-waste [EfW]), new and renewable energy (e.g. solar, batteries, micro-grids and biodiesel), and efficiency improvement and cost reduction (e.g. fusion, grid power electronics and power plant efficiency technologies). • The National Hydroelectric Power Corporation (NHPC), another PSU, solicits RD&D proposals directly from power plants (e.g. silt reduction, turbine components and station design). Other PSUs conduct some degree of RD&D, including the Damodar Valley Corporation (hydro) and Satluj Jal Vidyut Nigam Ltd (hydro and wind).

Public-sector RD&D priorities and co-ordination

At present, individual ministries are generally responsible for setting RD&D priorities, as they fund fuel- or resource-specific RD&D. For example, the MoC funds coal production research. As a result, most elements of India's public-sector innovation system support applied energy research tailored to a ministry's priorities, with the exception of DAE, which also supports basic scientific research. A smaller number of ministries support research on a wide variety of energy RD&D topics. For example, DST presently funds RD&D focusing on solar, energy storage, materials, coal, CCUS, building energy efficiency, smart grids, energy systems, hydrogen and fuel cells, and biomass and biofuels.

A certain amount of RD&D co-ordination occurs within ministries. For example, the OIDB co-ordinates research among the five regular RD&D grantee institutions of the MoPNG (see Table 6.1). At the MoP, a statutory body called the Central Electrical Authority chairs a Standing Committee on Research and Development, which reviews and approves power sector RD&D. Although DBT's five centres of excellence have an independent governance, different scientific advisory bodies, and partnership and funding models, the department promotes cross-centre connections. One centre, the DBT Pan-Indian Institute of Technology (IIT) Centre for Bioenergy, is a virtual centre of excellence spread across five different IITs located in Bombay, Kharagpur, Guwahati, Roorkee and Jodhpur, to expand geographic coverage and ensure co-ordination. As part of its support to the national Swachh Bharat Mission (waste-to-energy programme), DBT also organises regular workshops and conferences to bring together researchers, technology providers, industry users, policy makers and entrepreneurs, so that innovation activities remain aligned with national priorities and goals.

Efforts to achieve greater co-ordination among ministries are also emerging. In 2018 the Prime Minister established a Science, Technology and Innovation Advisory Council (PM-STIAC) to better co-ordinate efforts among ministries and establish common innovation priorities and frameworks. The council was set up with the express purpose of providing a cohesive direction to the science, technology and innovation system. In March 2019 the PM-STIAC acknowledged the need for increased support for innovation from government and industry, and identified nine new missions to address major Indian scientific challenges, including two directly related to energy (EVs, and EfW in support of the Swachh Bharat Mission). These missions will be led by the relevant government ministries and departments. In July 2019 the government also announced the possible creation of a National Research Foundation, which would promote, fund and co-ordinate research throughout the country, by pooling together the various research grants presently being awarded by independent ministries.

In recent years, on some occasions, a single minister has assumed responsibility for several ministries and their respective portfolios. For instance, the MoST and the MoES are presently supervised by a single minister. Similarly, the MoC, MoP and MNRE were under the supervision of a single minister between 2014 and 2017. Other practices could also be explored to enable inter-ministerial co-ordination, further improve collaboration and bring additional efficiency benefits to technology innovation.

Notably, India has also established an MI unit in DBT, in charge of co-ordinating RD&D activities related to MI.

Public-sector funding for energy RD&D

As a percentage of GDP, public spending on all RD&D in India has remained flat over the last two decades. India's gross expenditure on research and development as a percentage of GDP has been flat over the period 2015 to 2017 at approximately 0.69% (DST analysis).[1] This spending level ranks below that of other emerging economies such as the People's Republic of China ("China") (2.1%) and Brazil (1.3%). In absolute terms, however, public RD&D spending tripled from 2007 to 2017. The government has signalled a need to further support RD&D activities, for the country to progress "from net consumer to net producer of knowledge" (Ministry of Finance, 2018), including in the energy sector in accordance with Mission Innovation commitments.

In general, it is challenging to examine trends in *energy* RD&D expenditure among the various ministries and public departments due to a lack of detail on current budgets and expenditure. As part of MI, the MoST estimated that total central government funding for clean energy RD&D in 2014/15 was USD 72 million. India has pledged to double this by 2019/20. Table 6.2 displays reported clean energy RD&D spending under MI. Available data and preliminary analysis suggest a growth trajectory towards doubling over the five-year MI period. As of 2017/18, India's public-sector clean energy RD&D totalled USD 110.61 million.

Table 6.2 Clean energy RD&D spending in India (INR crores unless specified)

Department	Technology/area	2015/16 (baseline)	2016/17	2017/18
DST	Cleaner fuel and transport, solar, efficiency, smart grids, materials, etc.	50.01	109.87	159.7
MoP	Cleaner fossil fuels technology, efficiency	146.18	190.09	244.83
MoES	Clean energy technologies	3.95	4.38	6.15
MNRE	Solar, biofuels, hydrogen and fuel cells, wind, hybrids, solar heat pumps, etc.	43.75	59.75	81
DBT	Biofuels (liquid, solid biofuels and biogas)	18.14	30	45.85
MoNPG	Storage, biofuels, CCUS, materials, etc.	24.76	35.35	34.2
CSIR	Clean energy technologies	58.91	55.49	15.48
Others		49.83	87.61	159.39
	Total spending (INR crore)	395.53	572.54	746.6
	Total spending (USD million)	58.59	85.45	110.61

Source: Mission Innovation (2018), *Country Report and Progress Update*, http://mission-innovation-india.net/wp-content/uploads/2018/05/INDIA-Country-Report.pdf.

These MI amounts do not include major government RD&D expenditure on nuclear power (estimates point to INR 2 492 crores, or about USD 370 million) and fossil fuel energy

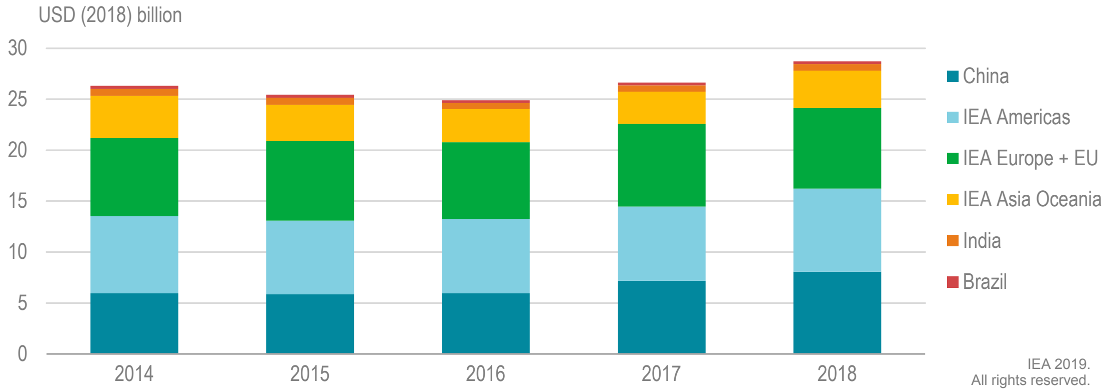
[1] DST indicators show expenditure/GDP stood at about 0.67% in 1990/91. It then increased and peaked at about 0.84% in 2008/09, before dropping and remaining below 0.70% since 2014/15.

(about INR 1 226 crores, or about USD 180 million).[2] PSUs also finance energy RD&D, including fossil fuel technologies such as the Advanced Ultra Super Critical Programme in coal power, jointly led by BHEL (MoHI), the Indira Gandhi Centre of Atomic Research (DAE) and the National Thermal Power Corporation (MoP), for an estimated cost of INR 1 554 crores (or about USD 230 million).

More detailed budgets and RD&D expenditure data, and further information about specific research programmes and areas in all relevant ministries, public research institutes and centres, and PSUs, would help innovation stakeholders better understand India's public-sector innovation framework, as well as its recent progress in an international context.

By global comparison, India's total expenditure is rather small (Figure 6.1), notably compared to China, the United States or Europe, corresponding to 0.23 per thousand GDP units, which is just under the IEA median of 0.33 per thousand GDP units.

Figure 6.1 Evolution of global energy RD&D public spending by region or country



Source: IEA (2019d), *World Energy Investment*, www.iea.org/wei2019/.

Private-sector energy RD&D landscape

While the public sector remains the main actor in India's energy RD&D landscape in terms of funding and leadership, the private sector is expected to play an increasingly important role.

India offers certain advantageous market fundamentals to the private sector, whether domestic or foreign, in the field of energy RD&D. For example, India's domestic market is of considerable size and boasts unique growth prospects, as projections point to India overtaking China as the world's most populous country by 2027. Over the years India has also trained a substantial pool of English-speaking engineers and scientists seeking technology development and entrepreneurial roles, and has built large-scale technology manufacturing (e.g. in semi-conductors) and digital capabilities. Make in India incentives

[2] To estimate fossil fuel energy RD&D activities, 2018 values from the MoC (INR 8 crores) and the MoPNG (INR 1 252 crores) are combined, excluding INR 34.2 crores already published under clean energy RD&D. Extra fossil fuel RD&D budgets from other ministries (e.g. the MoP) may increase these preliminary estimates (see Table 11.1).

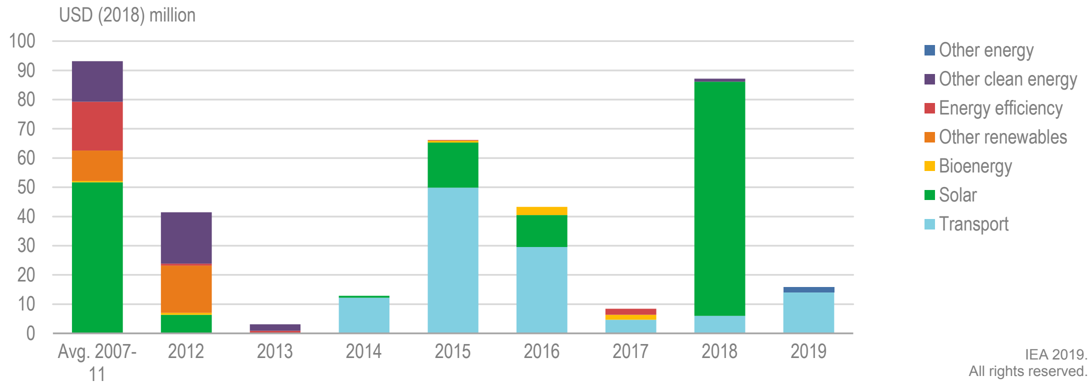
are likely to strengthen these capabilities. In addition, relative to some emerging and developing economies, India's legal framework, including for intellectual property, is well established.

For these reasons, there are encouraging examples of international energy companies opening research institutes in the country, such as Shell's centre in Bangalore, alongside its two other research centres in Amsterdam and Houston. In some instances, strategic policy making may also provide the appropriate incentives for private-sector involvement, such as the 2017 public procurement of 10 000 EVs to replace the government fleet of conventional fuel cars, which was awarded to Tata Motors and Mahindra Electric. Such "pull" factors stimulate the broader technology innovation ecosystem in the field of electric mobility: batteries, charging infrastructure, etc. Other initiatives, such as public-led Start-Up India or public–private partnership Global Innovation Technology Alliance, illustrate the government's commitment to stimulating domestic technology innovation.

Early-stage venture capital investments, as well as other corporate investments in RD&D activities, indicate the technology areas in which the private sector has decided to invest most when it comes to start-up companies. While activity remains limited in India, more early-stage venture capital activity (seed, series A, series B) was seen there in 2018 than since the 2012 "clean technology bust" (Figure 6.2). Most of this investment was in solar, and some in EVs, providing evidence that investors are bullish about the policy and market environment for these technologies in the near to medium term.

The IEA has identified USD 418 million of R&D spending reported publicly by Indian companies active in energy technologies in 2018. Further, Indian car makers spent around USD 900 million on R&D, a significant share of which was directed to more efficient and alternative fuel vehicle technologies.

Figure 6.2 Early-stage venture capital investment in energy technology



Source: Cleantech Group (2018), *i3 Database*, https://www.cleantech.com/i3/.

In 2018, DBT and its PSU, BIRAC, partnered with Tata Trusts to establish the CEIIC near New Delhi. It offers lab-to-market incubation support for clean energy entrepreneurs from MI countries. With a total initial investment of about USD 5 million, the incubator will promote innovation in clean energy by providing facilities and infrastructure, training and mentorship, shared consultancy services, intellectual property-related services, live test beds, seed support, exchange programmes and collaborations, and market linkages to innovators across the MI countries to test their technologies in local markets. The centre may also support end-use deployment of successful innovations. To date, selected start-ups are working on EV charging equipment and charging stations, solar-powered efficient machines for agriculture, biomass conversion equipment, innovative battery technologies, smart meters and data analytics platforms, zero-emissions turbine-based energy storage and power generation engines (Tata Trusts and Social Alpha, 2019).

However, private actor uptake of RD&D activities remains low in India relative to most countries. The concept of "frugal innovation" – a term applied to ingenious inventions that meet core user requirements without the backing of major corporate RD&D budgets or high levels of consumer finance – has found application in the energy sector, including via the use of novel information and communications technologies.

Box 6.1 Case-study • Public–private innovation partnership in advanced biofuels

India is positioned as a global pioneer in bioenergy innovation. It is co-leader of MI's challenge on sustainable biofuels, with a co-ordinating MI unit under DBT, and is also a member of the IEA Bioenergy TCP.

Developing sustainable biofuels aligns with India's broader national policy goals. In 2018 the government updated its National Policy on Biofuels to reduce oil imports, foster rural development and bring environmental benefits. It reaffirmed the need for bioenergy research such as the development of advanced biofuels from non-food crop feedstock. DBT and the MoPNG co-ordinate RD&D initiatives such as the DBT-IOCL Advanced Bioenergy Research Centre, near New Delhi.

Indian Oil Corporation Limited (IOCL) is a vertically integrated petroleum PSU under the MoPNG, and is among the country's largest and most profitable corporations. Since 2012 the DBT-IOC Centre has conducted research on lignocellulosic ethanol (a biofuel produced from non-food crop biomass, such as residues from cotton, wheat, rice or sugarcane), on issues related to pre-treatment, integration and scale-up. In 2013 a 250 kg/day cellulosic ethanol pilot plant was built with support from US National Renewable Energy Laboratory. The DBT-IOC Centre designed new enzyme production processes for biofuels development, achieving cost savings up to 50%. The centre also discovered the so-called simultaneous saccharification and co-fermentation (SSCF) technique, which reduces process time.

The DBT-IOC Centre recently began the construction of a 10 tonne/day biofuel production facility, co-located with IOCL's Mathura Refinery. The INR 1.10 billion (USD 16 million) project is expected to start operations by the end of 2019, a final demonstration step before commercial-scale production. IOCL and other petroleum PSUs are also building 12 bio-refineries using agricultural residue and municipal solid waste, for INR 100 billion (USD 1.5 billion). In 2018 Bharat Petroleum launched the construction of a rice straw feedstock-based bio-refinery in Odisha, with operations to start by December 2020.

The DBT-IOC Centre is one of five DBT joint centres of excellence specialising in bio-refining. The five centres mobilise a significant proportion of overall public investment in biofuels research. While the other centres are managed for DBT by an academic or non-profit organisation, the DBT-IOC Centre is co-funded equally by both entities. In addition, researchers have access to IOCL's engineering facilities and broader RD&D capabilities.

Sources: MoPNG (2018), National Policy on Biofuels; DBT-IOC (2018), "DBT-IOC Integrated Technology for 2G Ethanol", https://ec.europa.eu/energy/sites/ener/files/documents/17_s_k_puri-iocl.pdf.

Policy plays an important role in fostering private-sector engagement. Some public programmes in India, for example, do not allow private-sector companies to bid as lead applicant, or require specific certifications that may hinder and slow down private-led technology innovation processes, especially for SMEs. Tax breaks for RD&D activities, introduced at 200% in 2010 and to be reduced to 100% in 2020, are also important to stimulate corporate innovation, and their effectiveness may be strengthened with streamlined administrative procedures. There may also be a gap in support for the scale-up of emerging energy technologies, where capital costs and risks are high. Intellectual property frameworks may also need to be examined and strengthened, where relevant, to reach high protection standards and enable major corporations to confer RD&D leadership roles to their Indian satellite. Public research institutes, PSUs and academia may benefit from building closer ties with industry. In order to tap into greater investment and capabilities, and to accelerate energy RD&D, policy makers should address some of these components as they review innovation and energy policies.

International collaboration

A key element of India's energy RD&D approach is to maximise international collaboration to leverage the capabilities of partner countries, both to stimulate domestic innovation and to adapt best available technologies to Indian needs.

In recent years India has strengthened its engagement in key multi-lateral mechanisms and partnerships to accelerate energy innovation, notably under the Technology Collaboration Programme (TCP) led by the IEA and MI. In February 2019 India joined the Bioenergy TCP, bringing its total participation to 11 TCPs – that is the second largest among IEA partner countries. India has mostly focused on TCPs relating to energy supply technologies, including coal, bioenergy, ocean energy and fusion power, as well as on the TCPs relating to system integration technologies such as smart grids, demand-side management and hydrogen. There is also interest and potential for further engagement in other TCPs, such as photovoltaic power systems, and solar heating and cooling. A survey conducted by the IEA in 2019 shows that India has been identified by 14 TCPs as a strategic prospective partner country.

In practice, the government generally designates a public institution to lead Indian collaborative efforts, such as the MoP's BEE in the TCP on Demand-Side Management (DSM TCP), or the Institute for Plasma Research on nuclear fusion-related TCP activities. In one instance, a private company has become sponsor of a TCP, namely the conglomerate Reliance Industries Limited in the Hydrogen TCP.

India is a founding member and one of the leading countries under MI, and a key member of the Analysis and Joint Research sub-group. The government participates in all eight Innovation Challenges (ICs) and co-leads three of them: IC#1 on smart grids, IC#2 on off-grid access to electricity and IC#4 on sustainable biofuels. Much of this work is co-ordinated through the dedicated MI unit set up within DBT.

DBT also represents India in the steering group of the Biofuture Platform, a partnership of 20 countries with IEA support to accelerate the transition to a bio-economy. In 2015 India contributed USD 27 million to set up and host the International Solar Alliance from 2016 to 2021, a treaty-based intergovernmental organisation promoting affordable and sustainable solar energy across 121 prospective member countries.

India has established extensive bilateral collaborations with other governments to foster energy RD&D co-operation and attract foreign investment and human capital, including with the United States (e.g. Indo-US Joint Clean Energy Research and Development Centre in smart grids and energy storage; Bhaskara Advanced Solar Energy Programme; BHAVAN Fellowships in energy efficiency; Bioenergy Awards for Cutting Edge Research capacity-building programme), the United Kingdom (e.g. Joint UK-India Clean Energy Centre; DST–Research Councils UK collaborative projects on energy efficiency, storage and energy systems), Sweden and Japan (e.g. public–private co-operation and technology transfer scheme in iron and steel production).

Box 6.2 Case-study • Government support for MI Champions fostering clean energy access in rural India

Despite substantial improvements in electrification (see Chapter 2 on general energy policy), many Indians rely on kerosene lamps or diesel generators and face indoor pollution and expensive fuel. Innovation helps identify local solutions and the shift to cleaner energy sources, thereby contributing to national policy goals.

The micro solar dome (MSD) is a low-cost hybrid solar lighting device developed in 2016 by a Kolkata-based team from the NB Institute of Rural Technology (NBIRT). It concentrates daylight collected from a rooftop dome into an indoor ceiling dome. In addition to light, it provides heat in cold regions. Four versions have been developed, including a device paired with two solar panels, a battery and LEDs for night lighting, and USB charging. Production costs below INR 1 800 (USD 25) allow a payback in less than three months. The MSD innovation team was recognised as an International MI Champion in 2019.

Since 2015, as one of India's largest public-sector clean energy funding bodies, DST has supported the development of the MSD via long-term core support grants to the NBIRT. Under its Core Support Programmes, the Science for Equity, Empowerment and Development (SEED) Division funds scientific initiatives to develop technology solutions for rural areas. "Energy, lighting and fuel" is one of SEED's eight technology focus areas. Over 30 innovations have been developed, including devices for more energy-efficient agriculture, clean cooking and biomass use.

Approximately 4 000 MSDs have been installed experimentally, with promising results. Individuals report better quality of life, wealth-creation opportunities and easier education. In 2016 DST set an ambition to deploy 10 million MSDs and, as of 2019, it considers the technology ready for commercialisation. NBIRT is training locals to manufacture and install the devices. An inter-ministerial deployment plan is being crafted, building on past successes such as the UJALA programme, which has distributed nearly 350 million LEDs across India in the last decade.

Sources: World Bank (2017), SE4ALL Database: Access to Electricity Data; NBIRT (2019a), Micro Solar Dome: An Affordable Lighting Solution for Urban Slums, Rural & Remote Areas, www.nbirt.org.in/wp-content/uploads/2019/02/Micro-Solar-Dome-3-1.pdf; NBIRT (2019b), Micro Solar Dome: Network Mode Project, www.nbirt.org.in/wp-content/uploads/2019/02/Progress-Report-on-Micro-Solar-Dome-1.pdf; MST (2016), Photo-Voltaic Integrated Micro Solar Dome, http://pib.nic.in/newsite/PrintRelease.aspx?relid=153493.

Assessment framework

Designing a successful technology innovation ecosystem requires several components, beyond simply RD&D funding and alongside energy-specific considerations. A number of these components are illustrated in Box 6.3. A general environment of "doing business" and "doing innovation", for instance, may significantly influence the effectiveness of RD&D, regardless of national priorities in a given sector.

These components need to be aligned with policy goals and should be tracked over time to monitor progress.

Box 6.3 Components of an effective innovation ecosystem

Several elements are common to strong innovation ecosystems in IEA member or partner countries, including but not limited to RD&D public funding. Policy makers should also consider regional circumstances.

In general terms, Indian policy makers may consider focusing on certain high-level themes: ensuring a stable provision of financial and human resources to the innovation ecosystem; promoting knowledge generation in academia, research institutes and with corporate RD&D leaders; supporting markets with consistent incentives; and mobilising society in an inclusive, collaborative process.

- **Government support.** Given the high risks associated with investing in pre-commercial stages of technology development, governments play an important role in supporting innovation. They do this by setting national RD&D strategies consistent with long-term policy goals, investing public funds in projects led by national research institutions or international collaborations, and structuring markets and fiscal systems to provide incentives for private innovation.
- **Private-sector engagement.** Due to increasing pressure on public budgets, governments are leveraging corporate investments to foster innovation. Private actors seek to invest in market-led technology improvements and viable business models. With

appropriate incentives, private actors engage in partnerships with public institutions to undertake higher-risk projects, such as RD&D in capital-intensive energy technologies.

- **Vibrant knowledge society.** Human capital is the core of a country's innovation ecosystem (e.g. researchers and engineers). The ability to gain experience with existing technologies and acquire, retain and disseminate knowledge about emerging technologies, domestically and abroad, strengthens innovation processes. A variety of indicators can help policy makers create a vibrant knowledge society, such as: national academic achievement scores; the number of graduates, PhD candidates or patents in a given field; the availability of research support staff; the degree of domestic collaboration; the types of skills developed in academia; and the links between academia and industry.
- **Dynamic international networks.** Several levels of networks can enable innovative technologies and ideas to reach markets. Finance networks invest in start-ups at various stages of development. Academic and scientific networks help disseminate information via associations, conferences and international collaborations with both public and private stakeholders. Corporate networks help design supply chains for distributing new products, set standards and form strategic alliances.
- **Strong institutions.** An effective innovation ecosystem relies on a strong legal framework, with components related to intellectual property, standards for products and supply chains (e.g. safety, environmental and social) and market operations, etc. Norms of social behaviour and customer preferences may also be considered.
- **Tangible outcomes.** Key performance indicators (e.g. performance of individual components, capital costs and costs of energy services) for technologies under development need to be tracked and monitored to provide a feedback loop to innovators and policymakers.

As mentioned in Box 6.3, policy action may be required to develop some of the key components that foster technology innovation. Such policies include, but are not limited to, public RD&D funding. In practice, policy makers may consider a three-level approach: at the macro, meso and micro levels.

Non-financial support and policies

At the macro level, beyond energy-specific considerations, policies set the legal and institutional framework, and regulate business practices and market operations, thereby fostering economic development and the broader "doing business" environment. India's intellectual property regime would fall under such macro-level policies, as well as the country's higher education system, fiscal policies, innovation priorities and access to financing opportunities for entrepreneurs.

At the meso level, policies specific to the energy sector may steer technology innovation activities towards national priorities to achieve specific policy goals (e.g. reducing air pollution in urban centres). For instance, the ICAP includes RD&D activity components specific to the cooling sector, which fosters energy-specific innovation in a given technology area. "Pull" policies, which attempt to create market forces facilitating technology development (e.g. setting mandates, standards or quotas on the use of advanced biofuels), would fall under the meso category. While "pull" policies are not always considered as part of technology innovation policy packages, they have a significant impact on research-to-market processes.

Policy instruments for non-financial support include: intellectual property rights; technology transfer policies; access-to-finance regulations; national RD&D strategy; development of research institutions and academia; standards and certification policies (including environmental regulation); policies to establish technology innovation clusters; non-financial prizes and awards; policy intelligence (e.g. monitoring and evaluations); industrial policies with "pull" factors (e.g. mandates and quotas); national energy strategy (e.g. deployment targets and market structure)

Direct and indirect financial support

At the micro level, policy can support energy innovation via "push" levers, namely providing financial support for the development of new technologies. "Push" policies include allocating specific public RD&D funding to a given energy technology area (e.g. investing in advanced biofuels research).

Policy instruments for direct financial support include: grants for public research institutions, centres of excellence or private sector actors; procurement programmes for RD&D and innovation; fellowships and postgraduate loans and scholarships; loans, credits or guarantees for innovation in firms; equity financing; innovation vouchers for SMEs. Instruments for indirect support include tax incentives for RD&D activities.

Overall, policy makers may use a broad range of policy instruments to accelerate energy innovation. In addition to energy RD&D funding (micro, "push"), they should consider the broader energy policy landscape (meso, "pull"), as well as the general economic and technology innovation environment (macro, "doing business" and "doing innovation").

Assessment

Strategic planning of energy RD&D activities

Energy RD&D activities can be a strong enabler of India's energy policy goals, while also contributing to broader national priorities (e.g. Make in India). As a result, India is strengthening its innovation efforts in a broad range of energy technology areas (e.g. cooling, electric mobility, smart grids and advanced biofuels). At present, however, only in some cases are RD&D priorities directly embedded in key energy policies to align innovation efforts with national priorities. Examples of such policies include the ICAP (2019) or the National Mission on Transformative Mobility and Battery Storage (2019), which explicitly address technology innovation considerations, as detailed in previous sections.

The opportunity exists to systematically embed RD&D components in broader energy policies, so as to: a) conduct technology innovation activities that are synergetic with policy goals; b) ensure an inclusive multi-stakeholder process in designing RD&D roadmaps; c) foster engagement with non-public stakeholders to further leverage private investment; and d) enable greater policy ambition in the long term as new and more efficient technologies emerge (e.g. more ambitious emissions reductions).

A more impact-oriented approach to energy RD&D investments could also be promoted, that is, an approach that sets specific performance targets in key technology areas, such as the previously-mentioned India Global Cooling Prize. Other international RD&D approaches, such as the United States Advanced Research Projects Agency-Energy (ARPA-E), may provide examples of effective practices that aim to ensure the full innovation chain from lab to market is addressed.

Policy makers may benefit from laying out sectoral energy RD&D strategies and roadmaps that define priorities, desired results and monitoring processes across all technology areas, with several time horizons (for example, short and long term). Strategic planning should ideally engage with a wide range of stakeholders, including industry, academia, states and non-profits. Such a strategy could assess – based on national priorities and energy policy goals as well as capabilities and resources – whether it is best to adopt, adapt or develop energy technologies.

This holistic approach would: a) send strong signals to the broader energy innovation ecosystem as well as markets; b) improve the quality and effectiveness of domestic research institutions (both public and private); and c) foster long-term technology innovation growth, including in focus areas that may seem niche today (e.g. energy storage, net-zero buildings, CCUS, geothermal and marine energy).

Monitoring the results of energy RD&D funding appears to occur at the project level or as part of individual departmental results frameworks, and often focus on metrics such as the number of patents, citations and engagements. Data on energy-specific RD&D in India is limited, making it difficult to draw conclusions.

Key performance indicators and detailed funding history across RD&D programmes should be collected and monitored in a systematic manner, so as to adjust priorities and funding based on results. The IEA's efforts to collect, monitor and analyse data to track performance progress may be helpful in that regard, building on best practices developed in collaboration with IEA member and partner countries.

Inter-ministerial RD&D programme co-ordination

Many ministries and departments are engaged in directing, performing and funding energy RD&D. The greater the number of public institutions involved, the more challenging the co-ordination across RD&D activities can be. Ineffective co-ordination hinders the overall impact of innovation, as it becomes difficult to ensure efficient allocation of funds, time and staff, and to provide consistent signals to industry.

The innovation ecosystem in India would benefit from enhancing mechanisms to co-ordinate energy RD&D activities across ministries and public bodies. Such mechanisms would help avoid the fragmentation of initiatives, governance or responsibility dilution, overlaps or missed opportunities due to a lack of inter-agency visibility. They could bring substantial efficiency benefits thanks to lighter, streamlined administrative processes. The PM-STIAC, established in 2018, is a step towards enhancing co-ordination.

One way to further improve co-ordination could be to establish a senior-level governance structure composed of representatives from key ministries and research bodies, as well as administrative capacity for energy RD&D planning, policy development and co-ordination. This structure would contribute to the long-term consolidation of all public energy RD&D efforts, facilitate engagement with industry and strengthen India's role in international collaboration initiatives. The recently-announced National Research Foundation may be step towards this proposed co-ordination mechanism.

MI RD&D goals

As a percentage of GDP, public spending on RD&D in India has remained flat over the last two decades, and ranks below that of other emerging economies such as China and Brazil. The government has signalled a need to increase spending levels. For the energy sector, the country's role in MI illustrates these commitments. Although data on energy-specific RD&D in India is limited, preliminary reporting indicates that good progress towards MI doubling targets has been achieved.

The government is encouraged to maintain strong funding levels commensurate with the essential importance of the energy sector to India's rapid growth. Ongoing data collection on energy RD&D funding will be a key enabler in this regard and should be expanded to other levels of government, PSUs, academia and the private sector. The IEA and MST are collaborating in this context to map India's energy innovation ecosystem, identify innovation gaps and help track RD&D outcomes and innovation investment, based on the 2018 memorandum of understanding.

Private-sector engagement to spur energy RD&D investment

A distinct feature of the Indian innovation system is the dominance of the central government as the country's main RD&D funder. In most countries, the private sector drives RD&D spending and market-led technology innovation activities.

RD&D programming could be optimised to better spur private-sector investment and leadership. Engaging with private stakeholders is key to: a) leverage greater overall investment in technology innovation despite increasingly limited government resources; b) facilitate lab-to-market paths for key emerging technologies and accelerate deployment; and c) optimise the allocation of public funds in those specific innovation areas suffering from financing gaps due to higher risks and capital costs or longer-term returns on investment that are less appealing to private-sector actors.

The effectiveness of existing indirect measures (e.g. RD&D tax incentives) to stimulate broad-based industry innovation activity should be examined, in tandem with the current focus on targeted direct funding programmes. Intellectual property frameworks within energy RD&D programmes should also encourage private-sector participation and collaboration with public bodies and academia.

Leadership in energy RD&D international collaboration

As a co-founder of MI, co-leader of three MI challenges and participant in 11 IEA TCPs, an integral part of India's energy RD&D efforts is its focus on international collaboration.

The government is encouraged to continue these efforts and to aim at achieving concrete results for India. International collaboration may help the country develop and deploy emerging technologies necessary to achieve national policy goals, such as clean energy access, containing air pollution in urban centres and generally supporting robust economic growth.

Recommendations

The Government of India should:

- Work towards a more strategic approach to energy RD&D; systematically embed RD&D components in broader energy policies; lay out a long-term energy RD&D strategy and technology roadmaps; use impact-oriented results measurement at a broader scale than project level; systematically collect, monitor and make available detailed data on energy RD&D, including but not limited to funding.
- Establish stronger inter-ministerial co-ordination to clarify innovation priorities and consolidate energy RD&D activities, thereby improving the effectiveness of Indian RD&D despite increasingly limited resources.
- Follow through on the government's commitment to double clean energy RD&D funding, and ensure that ongoing funding levels align with India's rapid growth and national goals for energy access and sustainability.
- Make public energy RD&D programmes more accessible to the private sector and create incentives for private investment in energy innovation, from early R&D to commercialisation in line with Make in India.
- Continue to engage in international collaboration through bilateral and multi-lateral platforms (MI, TCP by IEA and other partnerships) to access available solutions in other countries and disseminate results from Indian energy RD&D.

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7. Electricity

Key IEA data

(2017*)

Total electricity generation: 1 532 TWh, up 86% since 2007

Total installed capacity (2019):** 365 GW, coal (55.8%), hydro (13.7%), wind (10.1%), solar PV (8.8%), natural gas (6.8%), bioenergy and waste (2.7%), nuclear (2%) and oil (0.1%)

Electricity generation mix: coal 74.0%, hydro 9.3%, natural gas 4.6%, wind 3.3%, bioenergy and waste 3.0%, nuclear 2.5%, solar 1.7%, oil 1.6%

Electricity consumption (by sector): 1 164.0 TWh (industry 40.0%, services [including agriculture] 34.0%, residential 24.8%, transport 1.2%), up 98% since 2007 with an average annual growth rate of 7%

*India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. So, the statement: “In 2017, electricity consumption (by sectors) was 1164 TWh” refers to the data India has collected (and supplied to the IEA) from 1 April 2017 to 31 March 2018.

**Installed capacity data as of 30/11/2019, which is sourced from the Central Electricity Authority (CEA).Small hydro is grouped together with hydro.

Overview

India is one of the largest electricity market areas in the world, comparable to the power systems of the European Union, the People’s Republic of China (“China”), the Russian Federation (“Russia”) and the United States. The national grid of India is the largest national synchronous grid in the world.

The Government of India (GoI) has focused on keeping up with strong demand growth, while expanding energy access to millions of consumers every year. After years of scarcity, India’s electricity system has now reached surplus power and good adequacy thanks to investment in thermal and renewable capacity, including from the private sector, which accounts for around 50% of the installed power capacity.

The GoI has been working to foster the financial health of the power sector. Long overdue reforms of power distribution companies (DISCOMs) are also taking shape, fostered by the central government Ujwal DISCOM Assurance Yojana (UDAY) scheme to decrease debt ratios. To avoid continuous bail outs of the DISCOMs by India’s governments, the GoI has announced plans to strengthen the UDAY scheme and introduce strict conditionality of government loans to the power sector as part of a new tariff policy. As the renewable energy sector has entered a period of very dynamic development, more efforts are needed to remove barriers to investment and maintain momentum, notably for distributed generation, such as solar photovoltaic (PV).

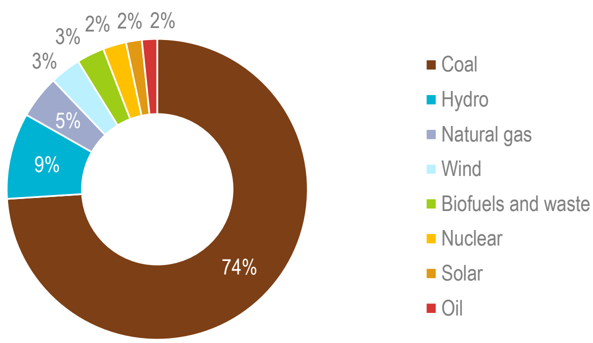
India has reached "one nation one grid" as it has synchronised its regional grids into one national grid at one frequency, but its markets remain fragmented, notably at the retail level, but also in wholesale trading. Structural reforms are under discussion to foster the creation of a wholesale market place for trading of power across India, including least-cost dispatch of electricity. The GoI is now tackling these structural concerns. In the context of surplus power, opportunities abound to carry out reforms to incorporate best practices from around the world. These particularly relate to the governance of power markets and systems to build a joint vison and enhance the role and collaboration of system and grid operators. India has built an institutional framework capable of providing the required investment. Reforms to this framework would allow greater economic efficiency, notably to boost cost-effective dispatch and balancing at the intrastate level, increase cross-border transmission capacity available for trades and better utilise existing assets. Today around 90% of trading is done through bilateral long-term contracts. This prevents efficient price discovery in the market, and leads to stressed assets and renewable energy curtailment.

Governance challenges at the interface between open markets and regulated services currently limit the opportunities for economic efficiency and consumer benefits. Structural market reforms are needed to further improve the financial stability, reliability and efficiency of electricity distribution. Reliable electricity supply to consumers can be fostered by introducing power quality norms, metering and billing, and moving towards cost-reflective and market-based tariffs.

Supply and demand trends

India's electricity demand has been increasing across most sectors, at an average annual rate of 7% during 2007-17. The largest consumption stems from the industrial and commercial sectors, although residential electricity demand is leading electricity demand growth.

Figure 7.1 Electricity overview – power generation by source, 2017



Coal accounts for three-quarters of India's electricity generation, which is consumed mostly in the industrial, commercial and residential sectors.

Notes: Bioenergy data are estimated by the IEA.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

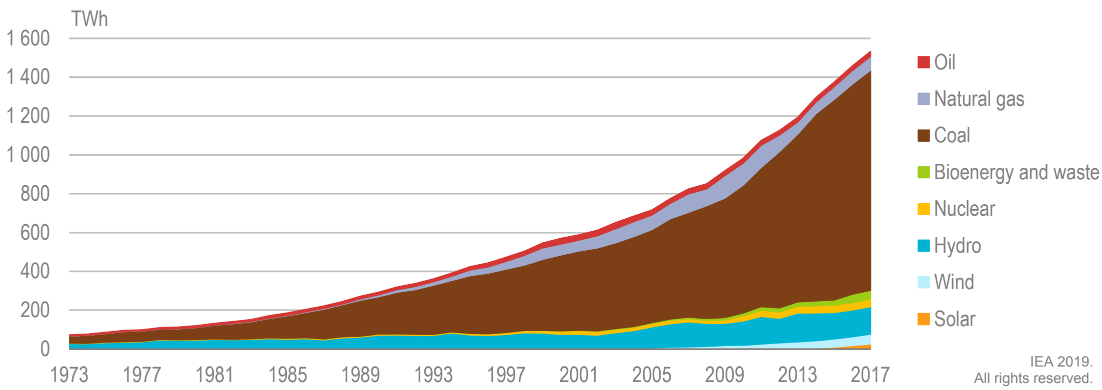
Most of the demand growth has been met by coal power generation, which accounted for nearly three-quarters of total electricity generation in 2017 (Figure 7.1), but also renewable power, in particular wind and solar, which increased rapidly supported by ambitious targets and policy measures.

Electricity generation

India's electricity generation has increased exponentially in the last decade, with an average annual growth rate of 6%. In 2017 total generation was 1 532 TWh, an increase by 86% since 2007 (Figure 7.2).

Coal power has met over 80% of this growth in electricity generation. Its share of total electricity generation has increased from 65% in 2007 to 74% in 2017. In 2017 gas power accounted for less than 5% of total electricity generation, down from over 10% a decade earlier. Hydropower is the second-largest power source in India, with 9% of total generation in 2017, down from 16% in 2007. Power generation from other renewables (wind, solar, and bioenergy and waste) accounted for 8% of total generation in 2017 (see further in Chapter 5 on renewable energy).Nuclear power is also increasing, but at a much slower pace than coal and renewables. In 2017 nuclear power accounted for below 3% of total electricity generation, but there are plans to increase its capacity in India.

Figure 7.2 Electricity generation by source, 1973-2017



Electricity generation has increased by 91% in a decade, mainly from coal power.

Notes: Bioenergy data are estimated by the IEA.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

The picture is different when looking at installed capacity (see Table 7.1): capacity has grown from 134 GW in 2008 to 248 GW in 2013 and 365 GW in 2019 (preliminary data), which has resulted in a good capacity margin over peak demand.

India's installed generation capacity is composed of

365 GW, coal (55.8%), hydro (13.7%), wind (10.1%), solar PV (8.8%), natural gas (6.8%), bioenergy and waste (2.7%), nuclear (2%) and oil (0.1%)

Solar installed capacity in India has increased rapidly from 2.63 GW in 2013 to 32.5 GW in 2019. While the share of renewables (wind, solar and bioenergy) was around 8% of generation in 2017, these sources made up around 21.8% of the installed capacity in 2017 (see Table 7.1).

The largest power markets within India are the states of Maharashtra, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Gujarat, Tamil Nadu, West Bengal, Andra Pradesh, Rajasthan and Karnataka (Figure 7.3).

Table 7.1 Evolution of installed capacity by fuel, 2013-18 (MW)

Fuel category	2013	2014	2015	2016	2017	2018	2019****
Coal*	145 273	164 636	185 173	192 163	197 171	200 704	204 224
Gas	21 782	23 062	24 509	25 329	24 897	24 937	24 937
Diesel	1 199	1 199	993	838	838	638	510
Nuclear	4 780	5 780	5 780	6 780	6 780	6 780	6 780
Hydro**	44 335	45 323	47 057	48 858	49 779	49 992	50 047
Wind	21 043	23 354	26 777	32 280	34 046	35 626	37 279
Solar	2 632	3 744	6 763	12 289	21 651	28 181	32 578
Biomass***	7 510	7 805	8 110	8 296	8 839	9 242	9 946
Total	**248 554**	**274 903**	**305 162**	**326 833**	**344 001**	**356 100**	**365 891**

*Includes lignite.

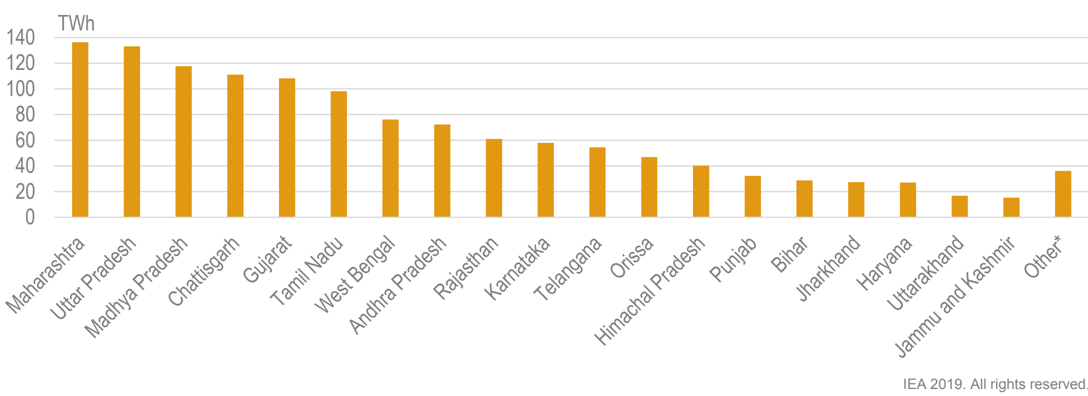
**Includes small hydropower.

***Includes biomass power/co-generation and energy-from-waste.

**** Preliminary data based on 30/11/2019

Source: CEA (2019a), *All India Installed Capacity*, www.cea.nic.in/reports/monthly/installedcapacity.

Figure 7.3 Electricity generation by state, 2018



**Other* includes Sikkim, Tripura, Kerala, Assam, Bhutan, Meghalaya, Arunachal Pradesh, Manipur, Nagaland, Mizoram and Goa.

Source: CEA (2019b), *All India Electricity Generation*; https://npp.gov.in/publishedReports

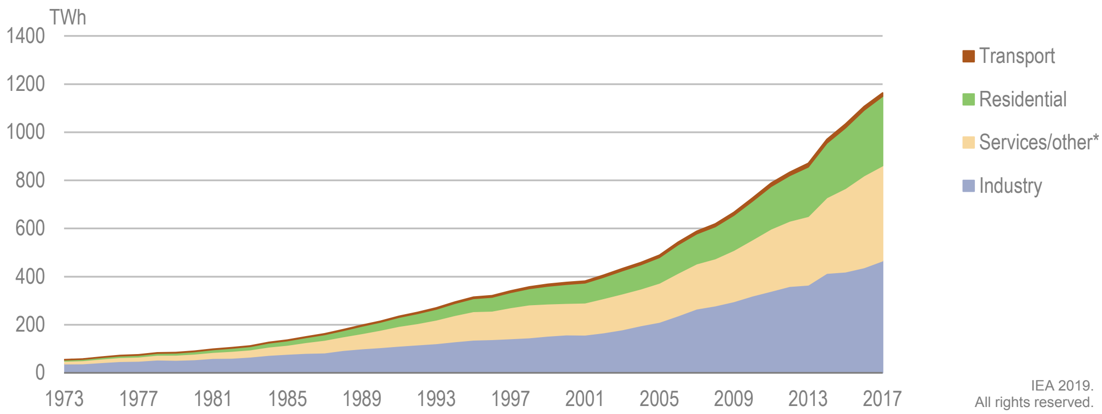
Imports and exports

In 2017 India became a net exporter of electricity after having been a net importer for several decades. The country has increased international power trade with neighbouring countries in Southeast Asia: in 2018 India exported power to Bangladesh, Myanmar and Nepal and imported power from Bhutan. India has developed new interconnections with Nepal and Bangladesh in recent years, as part of a greater regional integration move across South Asia. India plans to buy surplus hydropower from Bhutan and is putting in place investment and concessional finance to build hydropower in Bhutan and also in the Northern Indian territories.

Consumption

The industrial and service sectors are the largest users of electricity in India, accounting for 74% of total final consumption (TFC) together, roughly half each (Figure 7.4). Iron and steel, chemicals and petrochemicals, and textiles and leather are the industries with the highest electricity consumption (although nearly half of all industrial electricity consumption is not specified by sector). The service sector includes agriculture (demand for water pumping) and forestry, which account for half of the sector's demand. The residential sector is the third-largest electricity consumer, at 25% of total demand. The remaining consumption is used for rail transport.

Figure 7.4 Electricity TFC by sector, 1973-2017



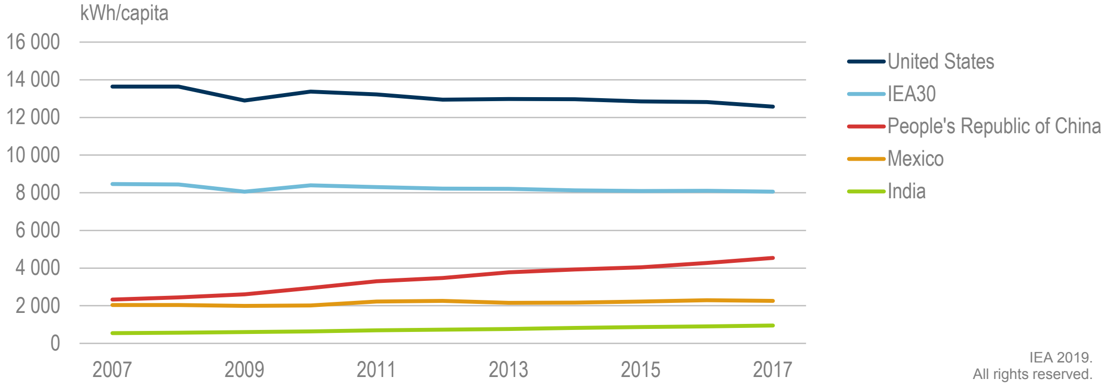
Electricity consumption has doubled in the last decade, and increased across all sectors.

**Services/other* includes commercial and public services, agriculture and forestry, and non-specified consumption.
Source: IEA (2019a), *World Energy Balances, 2019*, www.iea.org/statistics/

Industrial electricity demand has increased rapidly since the early 2000s and has continued to grow by 75% in the past decade. Service sector and residential demand have grown even more rapidly in recent years. Between 2014 and 2017 electricity consumption for services increased by 28% and by 26% in the residential sector. The residential demand growth has been driven by better access to electricity and increased use of electrical appliances.

However, per capita electricity consumption in India is still among the world's lowest (Figure 7.5). India's electricity growth rate per capita decreased in 2011/12, but overtook that of China in 2013/14 for two years (Figure 7.6). Future electricity consumption will be driven by growing electricity access, ownership of appliances and economic growth.

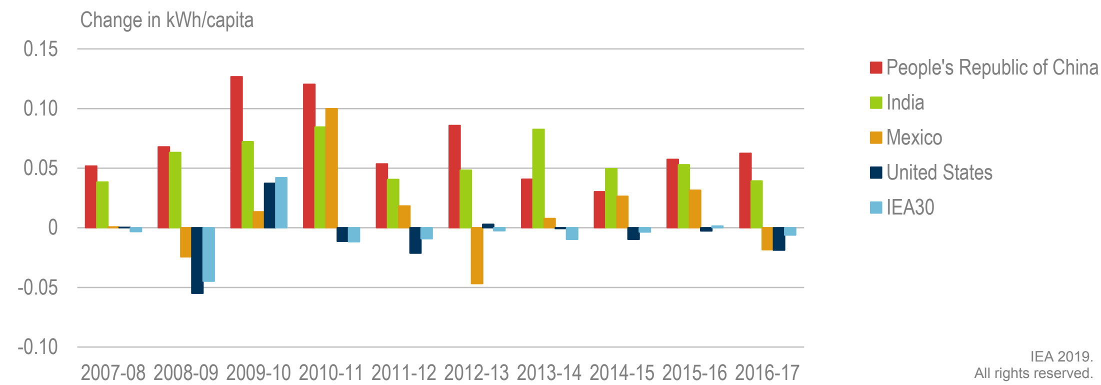
Figure 7.5 Evolution of per capita electricity demand in selected markets, 2007-17



Note: IEA 30 comprises IEA member countries.
Source: IEA (2019a), *World Energy Balances, 2019*, www.iea.org/statistics/.

With growing electrification of its villages, India's per capita electricity demand has grown consistently but on average more slowly than that of China and remained below expected growth rates. On a per capita basis, the United States and IEA 30 saw electricity demand flat and shrinking, as illustrated in Figure 7.6.

Figure 7.6 Evolution of per capita electricity demand in India and selected countries, 2008-17



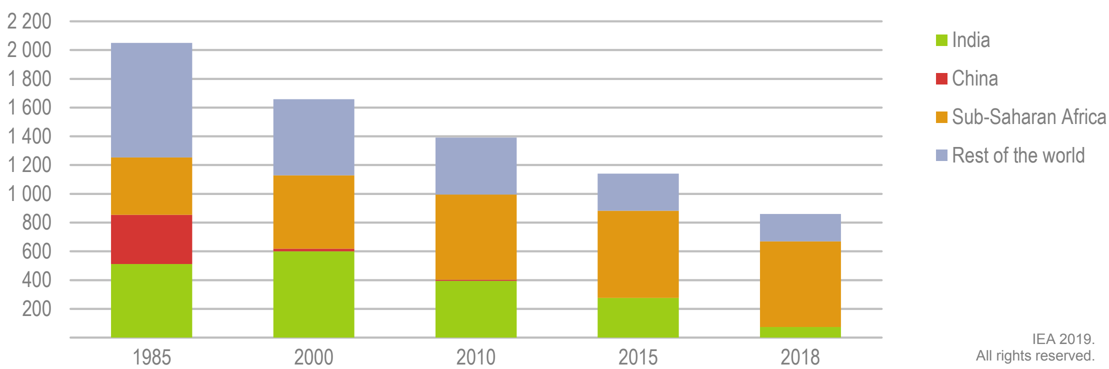
Source: IEA (2019a), *World Energy Balances, 2019*, www.iea.org/statistics/.

Electricity access

Over two decades India has made significant progress in providing universal electricity access to its population. Its electrification rate has increased very rapidly. After reaching 100% village electrification in 2018, within just a year, in March 2019, the GoI declared it had achieved the full electrification of all households (except those that refused access). The government supports the strengthening of distribution networks and increasing village and household connections by co-funding network upgrades and extensions. It provides grants through the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) scheme in rural areas, the Saubhagya scheme to ensure last-mile connectivity through mini-grid and stand-alone solar home systems, and the integrated power development scheme (IPDS) (in urban areas), building on the Restructured Accelerated Power Development and Reforms Programme. These efforts also supported the modernisation of the grid, including adoption of technology for data collection and monitoring, capacity building and customer care service. Besides providing access, these schemes have reinforced the transmission and distribution grids and driven the reduction in losses.

After implementing the programme for the electrification of villages and households, the GoI is now working to further improve access to clean and secure energy and to ensure full reliable access to electricity (with solar PV or batteries, notably in rural areas) and reach the remaining population. Despite good progress in electrification, there are still around 100 million people without access.[1] The rate of national access has grown from 43% in 2000 to more than 95% in 2019.

Figure 7.7 International comparison of populations without energy access, 1985-2018 (million people)



Source: IEA (2018a), *World Energy Outlook 2018*.

Institutions

Electricity is a concurrent subject matter in the Constitution of India: central and state actors can both legislate on the Indian power sector. In case of duplication, central legislation prevails (Figure 7.8; see also Chapter 2 on general energy policy, Figure 2.11).

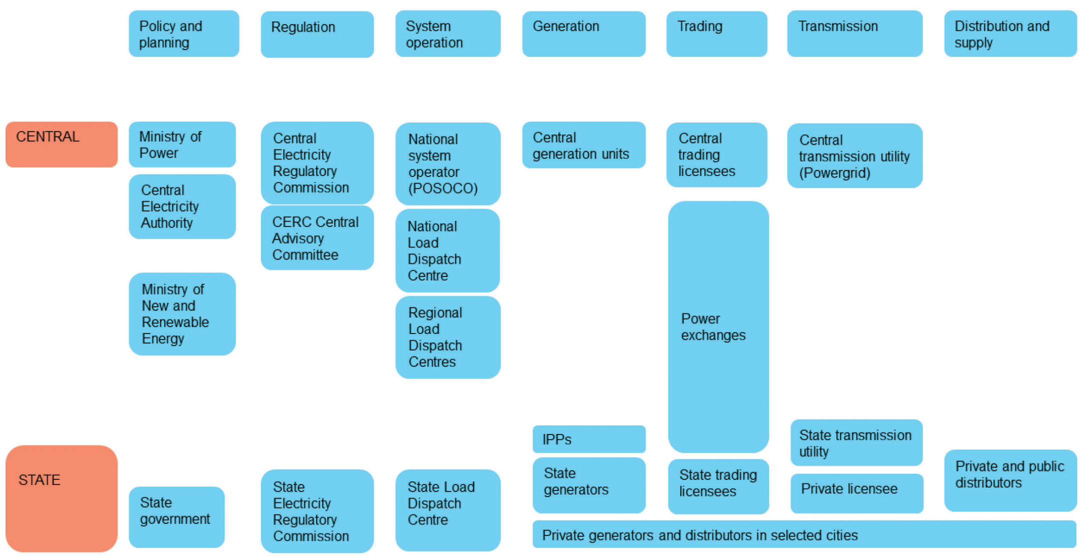
The **Ministry of Power (MoP)** is the highest central governing body and holds responsibility for policy, planning and project development and implementation. The **Central Electricity Authority (CEA)** is a technical organisation of the MoP, providing technical support to the MoP and all stakeholders in the power sector to inform the preparation of policies, technical standards and regulations based on monitoring and information dissemination.

Regulation at the central power market level is handled by the **Central Electricity Regulatory Commission (CERC)** under the mandates of the Electricity Act of 2003.

[1] Electrification rate can be measured in different ways. India has dual electrification targets that focus on both electrifying villages (a village is considered electrified if 10% of households and community services have access) and households. IEA methodology, however, focuses on the share of the population with access to electricity in line with the UN SDG tracking framework.

CERC determines the tariffs for generators owned by the central government and for those supplying electricity to more than one state. CERC sets the tariffs for transmission and is also in charge of the licensing interstate transmission and trading by generators, grid discipline and grid security, market development and market monitoring, as well as the promotion of renewable energy and energy efficiency by regulating the renewable energy certificates and the energy saving certificates. CERC also has oversight over the two power exchanges, the Indian Energy Exchange and the Power Exchange India. The Central Advisory Committee is in place to advise CERC on policy questions, compliance of power market licensees and standards of performance by utilities; however, it has no direct policy or regulatory control.

Figure 7.8 Structure of India's power sector



The **State Electricity Regulatory Commissions (SERCs)** regulate electricity generated by individual states' generators and sold within a single state. SERCs grant licences for intrastate transmission, intrastate trading and distribution. The GoI is planning a national-level selection committee for appointing chairpersons and members in all state electricity regulatory commissions to set the bodies free from political intervention and improve decision making at the central level.

The **Forum of Regulators of India** brings together CERC with the SERCs as a forum for discussion and exchange of views, based on model guidelines or regulations (model guidelines on rooftop solar and net metering rules, tariff rationalisation and tariff guidelines).

Market structure

India's power market activities are largely unbundled, based on the separation of generation, transmission and distribution under the Electricity Act of 2003, with retail activities been carried out mostly by DISCOMs. Generation does not require a licence.

While around 45% of generation is privately owned, the lion's share is owned by the governments (30% by the states and 25% by the central government) and unbundling of retail and distribution grid activities remains incomplete. Private investment is strongly growing in the area of renewables, and was previously the case for natural gas. There is a large efficiency gap between private and state-owned power plants (World Bank, 2019).

India's power market has around 600 generating stations, 30 transmission licensees, around 70 distribution licensees and two power exchanges with around 40 trading licensees. Similar to the European Union, India has power exchanges but no market operator.

India opened the electricity market to competition with the Electricity Act 2003. Many independent power producers (IPPs) have entered the market. However, the retail market is largely closed and has only limited competition. India has around 70 DISCOMs, most of which are state-owned and purchase power from generators, mostly through long-term power purchase agreements (PPAs), and sell them to residential, retail, agricultural, commercial and industrial consumers. Today the National Capital Territory of Delhi has a private DISCOM and seven other states have established private DISCOMs. All DISCOMs act as regional monopolies.

The power system is operated by the **Power System Operation Corporation (POSOCO)**, a state-owned company under the MoP. Since 2017 POSOCO has been fully responsible for ensuring the integrated operation of the grid in a reliable, efficient and secure manner through its five **Regional Load Despatch Centres (RLDCs)** and the **National Load Despatch Centre (NLDC).** It is fully independent from transmission activities.

Transmission

India has several electricity transmission operators across its territory. **Power Grid Corporation of India Limited** (Powergrid), a listed company with GoI holding 57.9%, operates under the MoP as the central transmission utility. Owning around 85% of India's transmission network, Powergrid owns and operates the interstate transmission lines, with a share of 40-50% of all transmitted electricity. It is required to ensure the development of a system of efficient, co-ordinated and economic interstate transmission lines, and to guarantee non-discriminatory open access to its transmission system, subject to availability of adequate transmission capacity. For the intrastate transmission systems these functions are performed by the state transmission utilities. There is a small number of private companies operating certain transmission lines. Powergrid also operates and maintains the international transmission interconnections with Bhutan, Nepal and Bangladesh.

Under the Electricity Act 2003 and Tariff Policy 2006, the MoP encouraged competitive tenders for transmission, based on the MoP "Guidelines for encouraging competition in development of transmission projects" and "Tariff-based competitive bidding guidelines for transmission services". Since 2011 all interstate transmission projects have to be implemented through tariff-based competitive bidding, except for some projects that are identified by the MoP for implementation by Powergrid (including projects that are strategic in nature, are technical upgrades or have time constraints as defined in Tariff Policy 2016).

By July 2019 India's interstate system had a length of 417 141 circuit kilometres and a transformation capacity of 917 843 megavolt amperes (MVA) (220 kilovolts [kV] and above). India's interregional capacity in the national grid stood at 99 050 MW, using alternating current (AC) lines of 765 kV and high-voltage direct current (HVDC) lines of 800 kV and above. India also has a special voltage of 1 200 kV AC, which was developed indigenously by Powergrid.

Captive producers

The high tariffs and erratic supply experienced by industry have led to a slow but steady decline in the growth of industrial electricity purchases from utilities and a gradual transition towards industry generating power itself (captive generation) or purchasing it from dedicated generators (open access). Around 18% of grid-connected capacity stems from so-called captive power plants, which satisfy 71% of India's industrial electricity consumption (ICPPA, 2018). India has around 80 GW of installed capacity in the form of captive power plants owned by industrial customers for localised production and use, stemming from the need for uninterrupted and affordable power supply for industry, amid relatively high industrial power tariffs. Captive power plants exist in diverse industries, including steel and iron, aluminium and metals, cement, chemicals, fertilisers, paper, textiles, sugar and engineering. The captive plants run on coal (54 GW or 68% of the total), natural gas (9.5 GW or 12%), diesel/fuel oil (3.5 GW or 4%) and renewables (bagasse, biomass, wind and solar) (15 GW or 16%). Load factors have been low for captive plants in the past two to three years, as the state-driven reduction of coal imports has led to a shortage of domestic coal, which has been mitigated by prioritising coal deliveries to critical power plants supplying residential and commercial users rather than industrial consumers.

System operation

India has achieved the integration of the five unsynchronised regional state grids, a process which started in the 1990s and was completed in December 2013. In 1991 the north-eastern and eastern grids were connected. In March 2003 the western region was interconnected, and in 2006 the northern grid was interconnected. This created four synchronously connected regional grids, northern, eastern, western and north-eastern, forming a central grid operating at one frequency. On 31 December 2013 the southern region was connected to the central grid in synchronous mode, thereby achieving "one nation-one grid-one frequency".

POSOCO operates the single NLDC and five RLDCs. The world's largest synchronous power system is operated via the NLDC, the five RLDCs and 33 State Load Dispatch Centres (SLDCs). The central-level power dispatch is divided into five regions: northern, western, southern, eastern, and north-eastern. DISCOMs work with SLDCs or have their own load dispatch department.

Power market reforms

The structure of India's power sector is the result of a long history of reforms, which were driven by the need to provide affordable, cleaner and secure electricity to the country's growing population.

India's Electricity Supply Act was first enacted in 1948. State electricity boards were set up and in 1951 the CEA was created to carry out the planning of the electricity sector.

The National Thermal Power Corporation (NTPC) and the National Hydro Power Corporation (NHPC) were created in 1975.

In the 1990s the Indian electricity sector was partially liberalised, with unbundling and privatisation (only one state electricity board was privatised). The 1998 Electricity Regulatory Commissions Act introduced the CERC and state regulators. The MoP enacted several State Reform Acts to modernise the power system at the state level and encourage private players to enter the generating sector as IPPs. The Electricity Act 2003 marked a complete overhaul of the sector and consolidated the many reforms that started in the 1990s. It removed licensing for the generation sector to create competition, but maintained the licensing of transmission and distribution operations. The 2003 act introduced open access to transmission and distribution.

The development of a competitive electricity market has been the key objective of the Electricity Act of 2003 and CERC has been the main driver of reforms, supported by the CEA. The Electricity Act of 2003 reinforced the role of the regulators – it mandated the creation of Electricity Regulatory Commissions in every state.

The National Electricity Policy 2005 provided guidelines to ensure access to electricity for all by 2012 and to foster the financial viability of the power sector, while keeping in view resource availability and security. The policy set out the strategic steps for securing private investment in the power sector, through captive power generation (large users), spot trading on exchanges and the formation of the Rural Electrification Corporation of India, aiding rural village electrification.

Market integration across India proceeded in several steps. In 2004 open access to transmission and distribution was introduced and power trading allowed. In 2007 the CERC guidelines created the power exchange. Only in 2008 was open access introduced to interstate transmission, which facilitated electricity trading at the exchange. In 2012 the 15-minute block became a new product at the exchange. To maintain grid discipline amid large power outages and frequency dips, CERC introduced unscheduled interchange charges in 2009, which were subsequently replaced by the Deviation Settlement Mechanism in 2014. Further, the Ancillary Services Mechanism was introduced in 2016 to reduce congestion, increase power trading and stabilise grid frequency. As one of the last milestones for regional trade across India, CERC established regulations governing the communication system for interstate transmission of electricity.

India’s central generators have an availability-based tariff (ABT), which is a frequency-based pricing mechanism for unscheduled electric power transactions. It was conceived to provide incentives and disincentives to grid participants against deviations in committed supplies. On the positive side, the ABT has streamlined the grid and system operation. Generator’s schedules are determined as per their share of generation in central stations. Any constituent that helps others by under-drawing from the regional grid in a deficit situation is compensated for the energy under-drawn. Second, the grid parameters, i.e. frequency and voltage, have improved and equipment damage correspondingly reduced. During peak load hours, the frequency can be improved only by reducing drawn electricity, and necessary incentives are provided in the mechanism to achieve this. A high frequency situation, on the other hand, is checked by encouraging a reduction in off-peak generation. Third, because of the clear separation between fixed and variable charges, generation is better aligned with its cost to the merit order. Fourth, a mechanism is established for harnessing captive generation and bilateral trading. By rewarding plant availability, the ABT supports capacity from thermal power plants and not renewable energy under PPAs.

The Electricity (Amendment) Act 2018, which is pending adoption in parliament, aims to introduce supply competition, wherein more than one service operator can supply power to a consumer in one distribution area, by introducing the separation of supply and distribution grid activities. This is intended to foster open access, competition and market dynamics, and provide greater impetus to renewable energy. It also proposes a new tariff policy, including the introduction of Direct Benefit Transfer for electricity subsidies (direct payment of subsidies to consumers' bank accounts rather than through the electricity tariff). The amendments include control of DISCOM's losses (if their losses go beyond a certain percentage, they will not be treated as a pass-through under the tariff). The policy also introduces penalties for the violation of PPA's in the order of INR 1 crore (or USD 140 000).

Assessment framework

Based on the characteristics and institutional governance of India's power system, including the level of interconnectivity, market/system operation and structure, the IEA in-depth reviews examine challenges and opportunities for power system transformation to foster environmental goals, economic efficiency and the security and reliability of the system. A good practice policy framework needs to satisfy at least three main objectives:

- align with environmental goals in support of the clean energy transition
- maximise the economic value of investments and consumer outcomes
- ensure power system security (adequacy/reliability, flexibility and resilience).

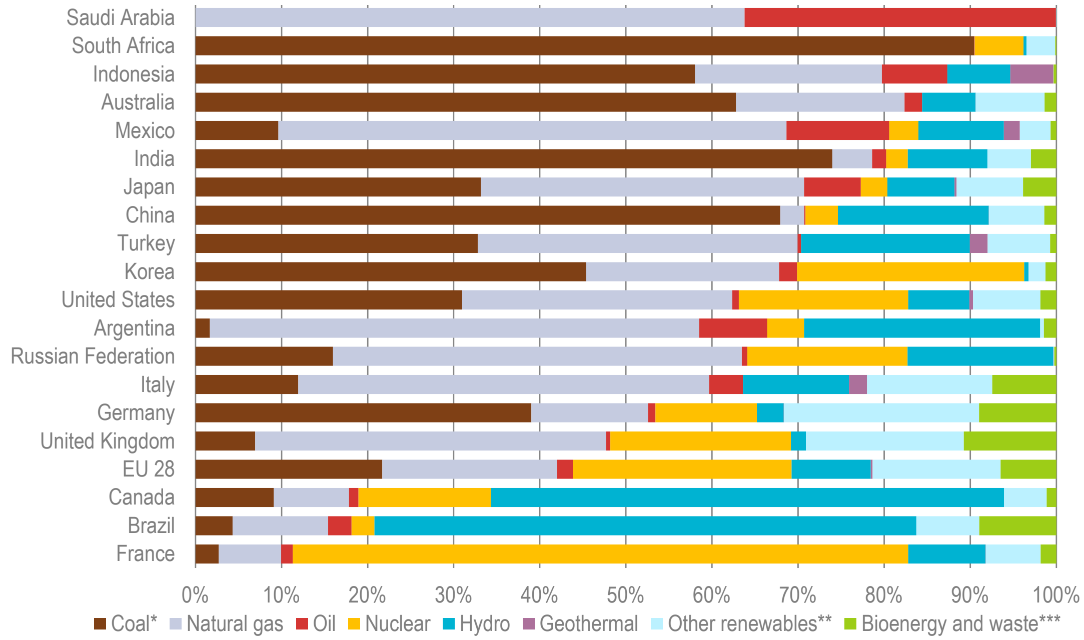
The following assessment is therefore divided in three parts (sections A, B and C). There is ample room for the identification of good policy practice and mutual learning, as IEA member and partner countries have undergone major electricity security reviews and reforms in recent years, which provide a wealth of experience and lessons for mutual exchange of knowledge, learning and collaboration.

A. India's power system transformation

Among the major economies, India takes the sixth position with regard to the share of fossil fuels in the electricity mix. The share of coal in the electricity mix is one of the highest in the world, after South Africa, and ahead of China and Australia (Figure 7.9).

The large share of coal power makes India's power generation highly emissions intensive. In 2017 India emitted 718 gCO_2 per kWh of electricity generated, according to the latest IEA data. This was 48% above the global average of 485 gCO_2/kWh and 15% above China's, whose CO_2 intensity in power generation has been consistently below India's since 2008 (Figure 7.10). The government stated in the country's commitment to meet the Paris Agreement, its Intended Nationally Determined Contribution (INDC), that India is aiming for 40% of its installed capacity to be from non-fossil sources – nuclear, hydro and renewables – by 2030 (UNFCCC, 2015).

Figure 7.9 Electricity generation by fuel in G20 countries, 2017



**Coal* also includes shares of peat and oil shale.

***Other renewables* includes wind and solar.

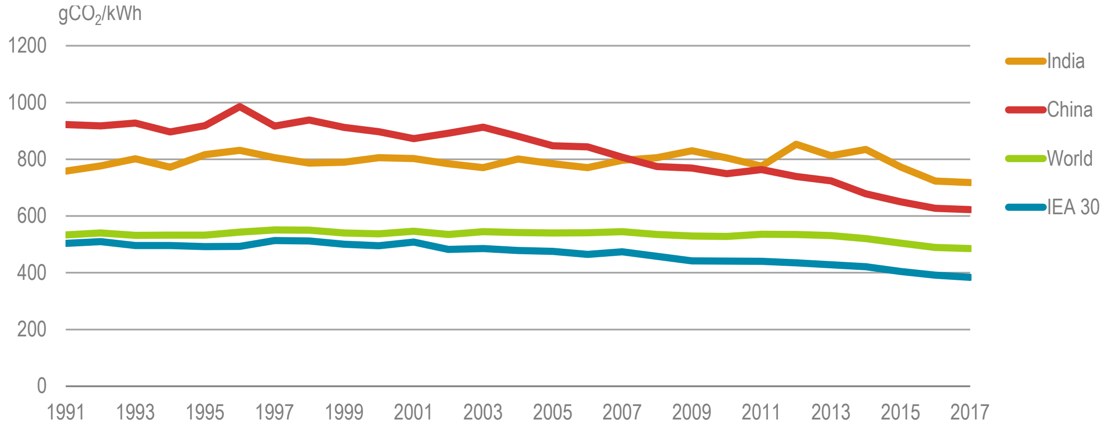
***Bioenergy data are estimated by the IEA.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

The GoI is targeting 175 GW of renewable power capacity by 2022, with 100 GW of solar (60 GW of utility-scale solar PV, 40 GW of rooftop solar), 60 GW of wind power, 5 GW of small hydro and 10 GW of bioenergy. By end of November 2019 grid-connected renewable electricity capacity reached 80 GW, with 32 GW from solar PV and 37 GW from onshore wind. Moreover, India has an objective to reach 63 GW of nuclear power capacity by 2032, a large increase compared to today's installed capacity of around 7 GW in 2019 (see nuclear energy section below).

Under the Electricity Act of 2003, the CEA prepares a National Electricity Plan in accordance with the National Electricity Policy once every five years. The 2018 Plan outlines that 23 GW of coal-fired capacity is set to retire during 2017-22 and another 26 GW during 2022-27. The GoI is aiming for the replacement of old inefficient coal-fired thermal units with supercritical units and the addition of gas, hydro, nuclear and renewables. By the end of 2022, 46.8% of India's installed capacity is expected to come from non-fossil sources such as nuclear, hydro and renewables, and 56.5% by 2027, which would take India far above the 40% stated in its NDC. In 2027 the country is expected to have 275 GW of installed solar and wind capacity, 72 GW of hydro and 15 GW of nuclear (CEA, 2018a). On the basis of these plans, the GoI aims to reduce the average CO_2 emissions intensity of power generation to 604 gCO_2/kWh in the year 2021/22 and to 524 gCO_2/kWh by the end of 2026/27.

Figure 7.10 CO_2 emissions intensity of power generation (including co-generation) in India, China, the IEA and the world, 1990-2017



Source: IEA (2018b), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Policies for decarbonisation

In India all electricity sector emissions are priced through taxes (OECD, 2018). Until 2017 India applied the so-called coal cess, an INR 400 per tonne tax on coal (USD 0.028 per tonne). Part of the revenue was directed to the National Clean Energy Fund to provide financial support to clean energy initiatives. The coal cess collected between 2010/11 and 2017/18 a total of INR 86 440 crore, out of which only INR 29 645 crore were actually transferred to the fund. The amount financed by the fund for projects was INR 15 911 crore (USD 2.24 billion), or 18% of the total amount collected from the coal cess. With the introduction of the Goods and Services Tax (GST), the coal cess was submerged under the GST and States received the compensation coal cess payment. In late 2019, the GoI proposed to cancel the coal cess altogether.India placed regulatory requirements on generators to retrofit coal power plants with desulphurisation units and pollution controls by 2017. The 2017 target was not met and was postponed until 2022. The Supreme Court brought the deadline forward to 2021 for power plants in heavily polluted areas (see Chapter 9 on coal for more details).

The role of nuclear power

The state-owned Nuclear Power Corporation of India Limited (NPCIL) is responsible for the design, construction, commissioning and operation of 22 thermal nuclear power plants, with a total installed capacity of 6 780 MW, comprising:[2]

- 17 small and medium-sized indigenously developed pressurised heavy water reactors (PHWRs) (about 220 MW and 540 MW) commissioned between 1980 and 2011.
- Two large Russian-built pressurised water reactors (PWRs) commissioned in 2013 and 2016 (1 000 MW each).
- Two small US-built GE boiling water reactors (BWRs) commissioned in 1969 (150 MW each).
- One small Canadian-built AECL PHWR commissioned in 1972 (100 MW).

[2] http://dae.nic.in/writereaddata/parl/budget2018/lsus4226.pdf.

Full details of these are provided in Table 7.2.

Table 7.2 Operating and under-construction nuclear power plants in India

Name	Type	Status	Location	Reference unit power	Gross electrical capacity	First grid connection
				(MW)	(MW)	(dd/mm/yyyy)
KAIGA-1	PHWR	Operational	Kaiga	202	220	12/10/2000
KAIGA-2	PHWR	Operational	Kaiga	202	220	02/12/1999
KAIGA-3	PHWR	Operational	Kaiga	202	220	11/04/2007
KAIGA-4	PHWR	Operational	Kaiga	202	220	19/01/2011
KAKRAPAR-3	PHWR	Under construction	Surat	630	700	
KAKRAPAR-4	PHWR	Under construction	Surat	630	700	
KAKRAPAR-2	PHWR	Operational	Surat	202	220	04/03/1995
KAKRAPAR-1	PHWR	Operational	Surat	202	220	24/11/1992
MADRAS-1	PHWR	Operational	Madras	205	220	23/07/1983
MADRAS-2	PHWR	Operational	Madras	205	220	20/09/1985
PFBR	FBR	Under construction	Madras	470	500	
NARORA-1	PHWR	Operational	Narora	202	220	29/07/1989
NARORA-2	PHWR	Operational	Narora	202	220	05/01/1992
RAJASTHAN-2	PHWR	Operational	Kota	187	200	01/11/1980
RAJASTHAN-3	PHWR	Operational	Kota	202	220	10/03/2000
RAJASTHAN-4	PHWR	Operational	Kota	202	220	17/11/2000
RAJASTHAN-1	PHWR	Operational	Kota	90	100	30/11/1972
RAJASTHAN-6	PHWR	Operational	Kota	202	220	28/03/2010
RAJASTHAN-7	PHWR	Under construction	Kota	630	700	
RAJASTHAN-8	PHWR	Under construction	Kota	630	700	
RAJASTHAN-5	PHWR	Operational	Kota	202	220	22/12/2009
TARAPUR-2	BWR	Operational	Boisar	150	160	05/05/1969
TARAPUR-3	PHWR	Operational	Boisar	490	540	15/06/2006
TARAPUR-4	PHWR	Operational	Boisar	490	540	04/06/2005
TARAPUR-1	BWR	Operational	Boisar	150	160	01/04/1969
KUDANKULAM-3	PWR	Under construction	Tirunellveli-Kattabomman	917	1 000	
KUDANKULAM-4	PWR	Under construction	Tirunellveli-Kattabomman	917	1 000	
KUDANKULAM-1	PWR	Operational	Tirunellveli-Kattabomman	932	1 000	22/10/2013
KUDANKULAM-2	PWR	Operational	Tirunellveli-Kattabomman	932	1 000	29/08/2016

Note: FBR = fast breeder reactor.

Source: IAEA/PRIS (2019), 01/10/2019.

The GoI included nuclear energy in the country's NDC (UNFCCC, 2015) and set ambitious targets to increase India's nuclear capacity, if the supply of fuel can be ensured. Its 12th Five-Year Plan for 2012-17 called for total installed nuclear capacity of 63 GW equivalent by 2032.

India has a total of seven nuclear reactors under construction, including four indigenous PHWRs totalling 2 800 MW, two Russian-built 1 000 MW PWRs and a 1 500 MW indigenous FBR. Moreover, India has discussed plans with France's EDF for six EPRs, with the United States for six AP1000s, and additional six VVERs from Russia. In January 2019 the government stated that plans for new nuclear would fall well short of its 2032 target of 63 GW and that the total capacity is likely to be about 22.5 GW (WNA, 2018). India's Department of Atomic Energy informed India's parliament that 21 new reactors with a total installed capacity of 15 700 MW are expected to be completed in the country by 2031. CEA's National Electricity Plan of 2018 confirmed 15 GW of nuclear by 2027.

India has a largely indigenous nuclear power programme. Due to earlier trade bans and lack of indigenous uranium, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium. Of its total capacity, 14 reactors with an installed capacity of 4 280 MW are under IAEA safeguards and use imported fuel. The remaining 8 reactors with an installed capacity of 2 400 MW use indigenous fuel. In 2008 India and the Nuclear Suppliers Group signed an agreement that opened the doors to international trade of nuclear technology and materials. Bilateral agreements with the United States, Russia, France, the United Kingdom, South Korea, the Czech Republic, Canada, Australia, Argentina, Kazakhstan, Mongolia, Namibia and Japan were signed.

Investment challenges in India relate to the liability of the vendor for all nuclear safety aspects, rather than the operator, which makes the import of foreign technology difficult (some bilateral agreements have special provisions to dispense with India's liability law). In 2016 the GoI asserted that "international and domestic concerns" over India's liability laws had been resolved with the 2015 establishment of the India Nuclear Insurance Pool, but suppliers remain hesitant to invest in India.

B. Electricity markets to maximise investments and consumer outcomes

The wholesale market

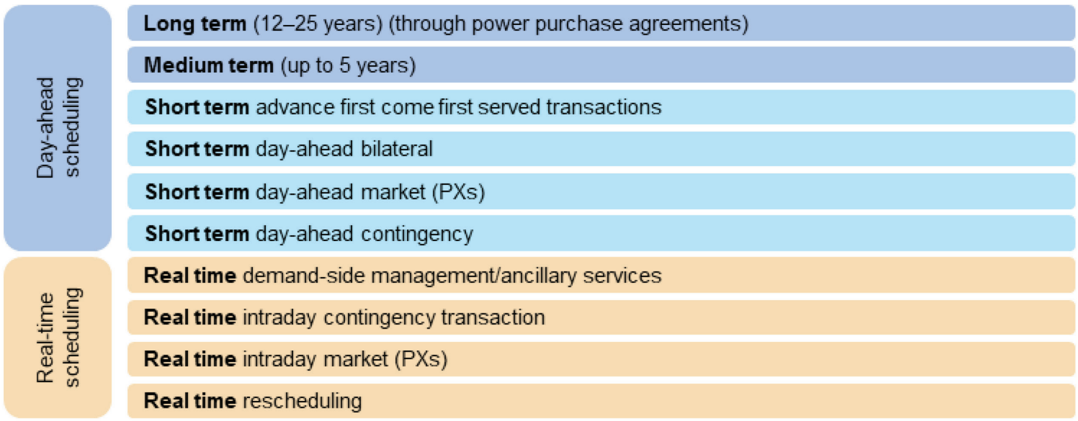
In 2008, two power exchanges were established in India: the India Energy Exchange and the Power Exchange India. Today there are five tradable products: day-ahead market (DAM) contracts, intraday and day-ahead contingency, and term-ahead market contracts. These are traded as follows:

- The DAM organises trading in 96 time blocks for 15 minutes, the day prior to delivery through a double-sided closed auction. The DAM has 12 geographically divided bid areas or price zones. In 2017/18, a total amount of 44 925 GWh was traded on this market.
- The intraday market offers power for delivery within the same day or day-ahead contingency with a gate closure of 3 hours.
- The term-ahead contracts involve delivery up to 11 days and can be daily or weekly contracts.

Renewable energy certificates (RECs) have been traded since 2011 and energy saving certificates (ESCerts) since September 2017 (weekly auctions).

India's power trade has four components: a) long-term, b) medium-term, c) short-term, and d) the balancing market. Long-term contracts in the form of PPAs, with terms up to 25 years, make up much of the power supplied in the country, while medium- and short-term contracts (three years to intraday) are traded over the counter and in power exchanges (see Figure 7.11).

Figure 7.11 India's power dispatch and scheduling



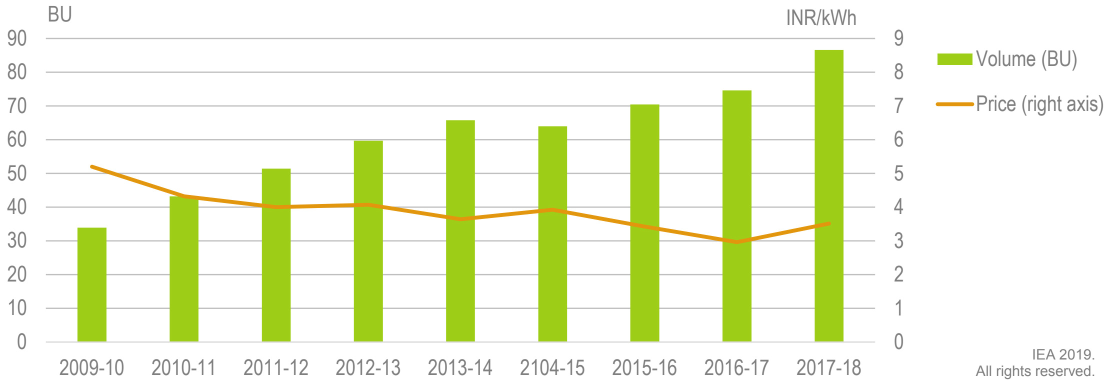
Note: PXs = power exchanges.
Source: Adapted from the CERC.

The power exchange segment has been growing most strongly, besides the rapid increase in the trade of RECs. An e-bidding portal (Discovery Efficient Energy Price Portal, DEEP) was launched to facilitate short-term procurement of power for the DISCOMs. Over the ten years since the creation of the exchanges, trades have increased consistently, with market clearing prices in decline (only financial year 2017/18 saw a slightly higher price due to the coal shortage) and trading volumes on the rise (Figure 7.12). However, system operators (SLDCs or the DISCOMs) still schedule generators based on long-term contracts and not on the basis of the merit or least-cost dispatch order. The deviation settlement mechanism (DSM) is the main tool for settling real-time imbalances. Surplus capacity from interstate generators is regulated by the CERC – the surplus has to be made available through the administered ancillary services mechanisms.

The power exchanges offer an instrument for efficient price discovery and prices have been consistently below than those in long-term contracts (IEX, 2018): DISCOMs and industry consumers can source cheaper power through the exchange to meet shortages and reduce their input cost. However, several states have increased the cross-subsidy surcharge and introduced additional charges, making purchases from the open market more expensive, while at the same time making sure long-term capacity contracts are used first.

CERC has been playing a strong role in the development of a power market in India, by creating an enabling framework for a multiple buyer–seller model, facilitating the operationalisation of open access, and creating a range of short-term markets. These reforms have enabled a drop in price and an increase in trading volumes (Figure 7.12).

Figure 7.12 Trading volumes and prices at the IEX

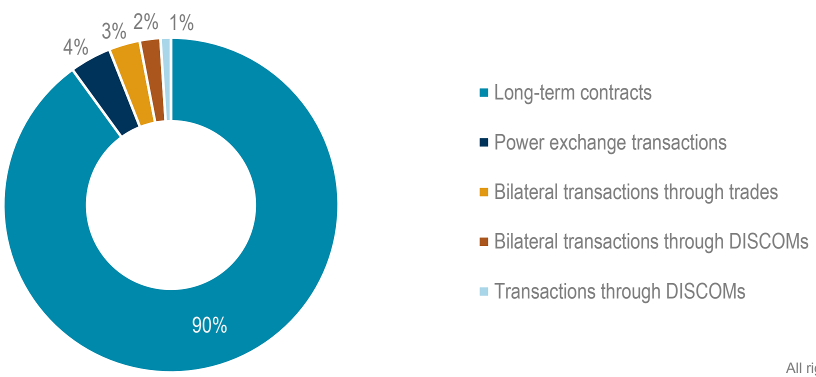


Note: BU = TWh.

Source: CERC (2018), *Report on Short-Term Power Markets, MMC Report 2017-18*, www.cercind.gov.in/2018/MMC/AR18.pdf.

In the financial year 2017/18 around 90% of all generation was priced through regulated (cost-plus) long-term contracts and only 10% was traded in the short term: 5% was traded over the counter (one year), 4% on the exchanges (11 days) and 2% in real time (deviation settlement), according to CERC latest data (Figure 7.13).

Figure 7.13 Volume of electricity traded



90% of all generation was priced through regulated long-term contracts, with only 4% through the exchange.

Source: CERC (2018a), *Report on Short-Term Power Markets, MMC Report 2017-18*; www.cercind.gov.in/2018/MMC/AR18.pdf.

Wholesale market reforms

Over the past decade, power market reforms in India have targeted increases in open access and trading across the Indian power system with the aim of fostering access to reliable, affordable and cleaner energy, making optimal use of India's resource endowment across the regions. In view of rising share of renewable energy, wholesale market reforms are critical for the system integration of renewable energy (see section C of this Chapter and Chapter 8 on system integration). Based on an in-depth analysis of trade barriers and international experience gained in market design reforms, in 2018 CERC released three discussion papers to promote a series of important wholesale market reforms, which aim to reduce the barriers to trade in the different time horizons and markets: a) Redesigning Real Time Electricity Markets in India (CERC, 2018b); b) Market-Based Economic Dispatch of Electricity: Redesigning of Day-Ahead Market in India (CERC, 2018c); and c) Redesigning Ancillary Services Mechanism in India (2018d).

- **DAM:** The lack of an efficient DAM allowing the optimised dispatch of power plants across the country is among the biggest challenges. The PPAs between DISCOMs and thermal generators are not flexible, as state-owned power plants hold legacy long-term fuel supply agreements (FSAs), through so-called coal linkages, and have not been able to trade on the power exchanges[3]. This makes it challenging for generators to bid into the wholesale market, even if they technically have idle capacity, and for DISCOMs to identify and purchase cheaper or free supply. Several reforms have been adopted to improve access to short-term trading for existing contracts.[4]
- **Ancillary services:** In India, only regional (interstate) generators are obliged to provide ancillary services. NLDC is the nodal agency for stacking the merit order. To date, ancillary services are mainly provided from thermal power stations, but hydro plants are at the pilot stage with CERC. DISCOMs are not paid for the reserves they hold for ancillary services.
- **Real-time market**: An intraday market was introduced in the power exchange to address the need to meet energy requirements closer to real time. However, the performance of this segment of the market has not been encouraging. The lack of an enforceable gate closure, i.e. a moment where a bid by participants becomes a binding commitment to sell or buy electricity, makes intraday trading unfeasible, as bids can be recalled without penalty. Ancillary services and the DSM are used for real-time energy management.

CERC proposed the creation of a central electricity market for day-ahead and real-time dispatch, which would be co-optimised with the procurement of ancillary services. For the DAM, the proposal is a market-based economic dispatch run by a central market operator (with voluntary participation of generators) that would replace self-scheduling and include congestion management and market splitting. With regard to contractual financial obligations in existing PPAs, bilateral contract settlement is proposed to make the best use of existing assets, while respecting the contractual commitments of DISCOMs. Generators would also be able to participate in the market without having a PPA.

Reforms are under preparation to create forward contracts to increase the options for hedging, which are currently not available in India. The CERC regulations for Open Access in Interstate Transmission require the creation of a National Open Access Registry as a centralised electronic platform owned and operated by the NLDC.

In 2019 the central government is running a pilot for least-cost dispatch with POSOCO and the centrally regulated interstate generators.

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[3] A coal linkage is the allocation of scarce domestic coal among thermal power plant generators. The central government designated the Central Electricity Authority to design and issue methodology for coal linkage. States who have assigned coal should follow these guidelines while allocating the assigned coal among their own generating stations, other state generating stations, Central Government Stations and Independent Power Plants (IPPs- mostly private).

[4] Recent reforms provide for more market-based approaches and flexibility. Power plants that do not have PPAs today are now allowed coal linkages for between 3 months and 1 year, if they sell in the DAM or short-term market (DEEP)). The new coal linkage policy (SHAKTI) improves coal supplies to (private) plants that did not have FSAs. States can provide coal linkages to DISCOMs to auction new PPAs.

Box 7.1 International experience – Nord Pool

Nord Pool is the most advanced European power market, spanning the Nordic (Norway, Sweden, Denmark, Finland) and Baltic states (Estonia, Lithuania, Latvia), and coupled with different regional electricity markets. Nord Pool is a nominated electricity market operator (NEMO) in the EU internal electricity market and operates in 15 European countries, while also servicing power markets in Croatia and Bulgaria.

Nord Pool is owned by the seven Nordic and Baltic transmission system operators (TSOs). The role of the Nordic TSOs was fundamental to the launch of Nord Pool in ensuring sufficient interconnection capacity and seamless co-ordination between market and system operation on the basis of the same principles. Most notable were the common rules based on a joint Nordic merit order list for a specific operating hour, so as to organise balance management across the Nordic control areas as one system across all four TSOs.

Created as a mandatory pool, all generators are obliged to sell their electricity through the pool. This has reduced the market power of the generators in their national markets. Transparency, neutrality and equal treatment (and access) for all parties are key cornerstones of a sustainable market. Elspot is the day-ahead market and Elbas the intraday market (for capacity not used in Elspot). A common Nordic Balance Settlement has been in place since May 2017. In 2017 the Nordic market volume traded on the day-ahead market reached a total of 391 TWh, with 5 TWh traded on the intraday market. Financial contracts are used for price hedging and risk management with a time horizon up to ten years, covering daily, weekly, monthly, quarterly and annual contracts. The system price calculated by Nord Pool is used as the reference price for the financial market in the Nordic region.

Intraday gate closure between Finland, Latvia and Estonia is currently being piloted for 30 minutes (instead of 60 minutes in the Nordic market). Since the introduction of this shorter gate closure, intraday trading volumes have increased. The price cap in the day-ahead market is EUR 3 000 per MWh and EUR -500 per MWh. Discussions are ongoing to increase the price cap in the intraday and balancing power markets to reflect the increasing need for flexibility.

The Nordic states have one or more bidding zones to reflect congestion and signal network investment needs. Congestion in national and inter-regional lines is managed by countertrades. Through the so-called ‘price coupling of the regions’, market coupling is in place between the Nordic countries, the European continent and the Baltics and the Southern European markets.

The EU has adopted a set of common network codes and framework guidelines (system operation, market rules and grid connection) for the entire market place, which are adopted through a formal process involving the European Commission, the Agency for the Co-operation of Energy Regulators (ACER) and the European Network of Transmission System Operators (ENTSO-E). The latter also plans the transmission network investment in a ten-year horizon and assesses the short-term outlook for the winter and summer with regard to the system adequacy, based on a European approach.

CERC has also tabled proposals to introduce intraday trading regulations. It has recently reformed the deviation settlement mechanism to improve forecasting and planning by moving from administrative penalties to market-based penalties linked to the average price in the DAM. An ancillary services market co-optimised with the DAM and real-time markets would allow the procurement of tertiary reserves (15-30 minutes). CERC is also targeting amendments to grid connectivity rules, including the definition of stand-alone storage, and the ancillary services market. It is already looking at the next level of reform, which would introduce financial transmission rights, locational pricing and market monitoring and surveillance.

To foster trade with neighbouring countries and underpin India's growing power exports, in March 2019 CERC adopted regulations on cross-border trade of electricity, which apply to participating entities in India and neighbouring countries. The regulations set out the roles and responsibilities of system operation, payment security and transmission capacity, among other matters.

Experience in international power markets shows that power reforms take time. They require a gradual learning process for all stakeholders, a strong reform agenda and a joint vision that is shared by states, central government, system operators and all regulators as well as market participants. The successful experience of Nord Pool in the European Union relied on the role of the transmission system operators and their support for wholesale market creation by ensuring efficient transmission capacity and trading across large interconnected systems (see Box 7.1). Under the EU Electricity Regulation of 2019, 70% of cross-border transmission capacity needs to be offered to the market. The key objective is to promote the liquidity and depth of the power market. In the Nordic power market, all available transmission capacity between the different market areas was given to the market, the only route to cross-border trading. The European Union has introduced market coupling to achieve gradual market integration across the regional grids in the one synchronised zone.

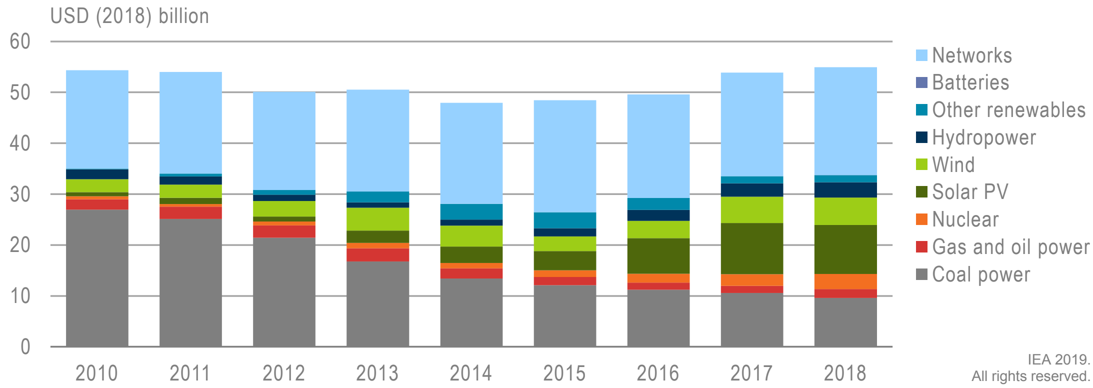
Investment in the power sector

Investment patterns in India's power sector are largely reflective of the country's energy transition goals. Final investment decisions for new coal power capacity fell to a historic low in 2018 (after 15 years), while investment in renewables reached USD 20 billion and for the first time overtook total investment in the thermal power sector.

Power sector investment in India has increased since 2015 thanks to strong solar PV and wind investment, which compensate for the fall in new coal plants. Network spending has remained at historical highs, accounting for more than a third of total power sector investment (Figure 7.14). Investment in renewables has been driven by a more than doubling of solar PV investment and record spending on onshore wind projects.

Despite overall policy signals, investment in dispatchable renewable power plants, notably hydropower and bioenergy, but also gas power, has remained relatively low. There are a number of risks on the horizon, notably for renewable investment in India (for a detailed analysis see Chapter 5 on renewable energy), which relate to the poor financial health of the DISCOMs, safeguard duties imposed on solar PV and module imports, delays in land acquisition, transmission infrastructure hold-ups and the poor design of competitive auctions in India. The safeguard duties alone led to the cancellation of around 5 GW of solar PV projects awarded in 2018.

Figure 7.14 Power sector investment, 2010-18



Source: IEA (2019b), *World Energy Investment Report 2019*.

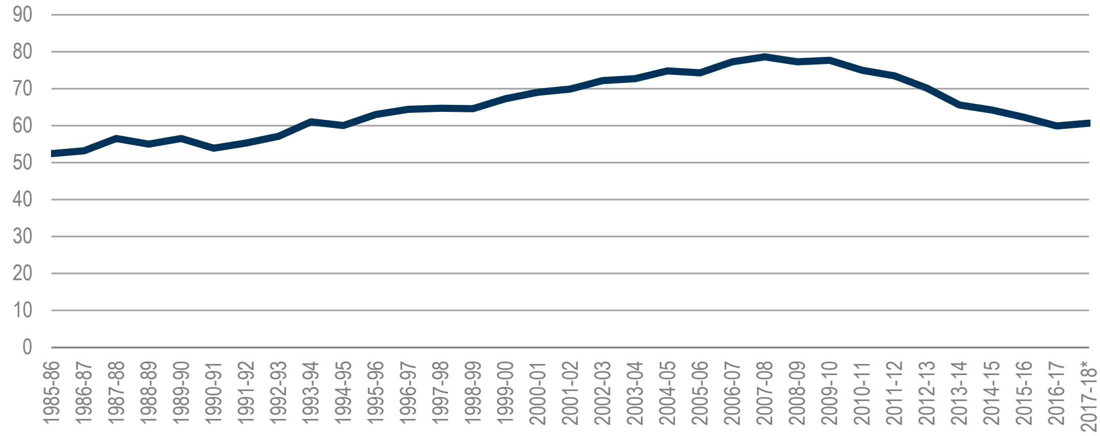
The cost of equity and debt financing amounts to 60% of the levelised cost of electricity from solar PV and wind projects, according to the 2019 clean energy investment trend report by the IEA, CEEW and Centre for Energy Finance (CEEW and IEA, 2019). In fact, the share of debt used for solar PV projects has been on the rise, and renewable and thermal investment projects compete for scarce long-term and fixed-rate debt. Competitive auctions for solar PV and wind power have seen very aggressive bidding, leading to very low auction prices.

Power assets under financial stress

India has around 54 GW of capacity that is financially unviable and is qualified to be "under financial stress". Out of India's total installed capacity of about 356 GW, around 40 GW of coal-fired capacity and 14 GW of gas-fired capacity are considered as non-performing assets (HLEC, 2018).

In 2017 installed gas-fired power capacity stood at 25 GW (7% of all capacity). However, its share of generation was only 5%. A total of 14 GW of gas-fired capacity is stranded due to non-availability of domestic gas and unaffordability of imported gas. Among the 31 stranded plants, one is a central power plant and six are state plants, while the overwhelming 10 GW majority belongs to the private sector (Parliament of India, 2019). Many of these cannot service their debt with Indian banks. The private sector invested in gas-fired power during the mid-2000s with the expectation of being able to secure gas supplies from domestic production (87 million cubic metres per day [mcm/d]). However, during 2017/18 only 25.7 mcm/d was available since domestic production from the KGD6 gas field stopped. The plant load factor of gas power plants stood at an average of around 23% in 2017, a sharp decline from 67% during 2009/10. In 2010 India's gas allocation policy prioritised the power sector; in 2013 the government started prioritising city gas distribution systems amid the lack of gas supplies (Parliament of India, 2019).

Figure 7.15 Plant load factor of thermal generating stations (hard coal and lignite)



*2017/18 data are provisional.

Source: CEA (2018b), *Plant Load Factor of Thermal Generating Stations (Hard Coal and Lignite)*, http://cea.nic.in/plant_load_factor.html.

Some 40 GW of coal-fired power generating capacity (with 15 GW under construction) is considered a stressed asset due to a combination of factors, involving surplus capacity, the higher cost of coal (due to higher transport and import costs), low demand, increased competition from renewable energy and lack of timely payment by the financially stretched DISCOMs (HLEC, 2018).

Plant load factors have fallen in response to overcapacity, averaging 60% in 2016/17 and 61% in 2017/18 (Figure 7.15). Because the private-sector plants do not have FSAs (after the change in the coal allocation policy in 2013), they have to bid for coal supplies but do not receive compensation through the new coal compensation cess, which is available to public plants. (For discussion on the profitability of the power companies active in India, see also Chapter 2 on general energy policy, public-sector undertaking rankings versus private company financial performance).

The DISCOMs incur huge financial losses due to poor infrastructure and weak or non-collection of revenues from consumers, linked to power theft, lack of proper metering and billing, and social policies (low tariffs).

By the end of 2019 the DISCOMs had an outstanding debt of USD 9.9 billion to thermal power plants and USD 1.3 billion to renewable generators. Aggregate technical and commercial losses are on average around 20%, while in some states' DISCOMs have losses of up to 50% (see Figure 7.16).[5]

[5] See detailed information on DISCOMs' outstanding debt and invoiced amounts on the website of the MoP, *Payment Ratification and Analysis in Power Procurement for Bringing Transparency in Invoicing of Generators*: www.praapti.in/. See also Brookings India (2019).

Box 7.2 A government package for stressed assets

In the gas and coal sectors, the GoI adopted measures to increase the supply of the commodities. In 2015 it held e-auctions for liquefied natural gas (LNG) imports to go to stranded gas-fired power plants, with a financial support subsidy from the Power System Development Fund, which compensated for the higher cost of imported LNG versus domestic gas supplies. The scheme expired in 2017 as several states did not want to participate.

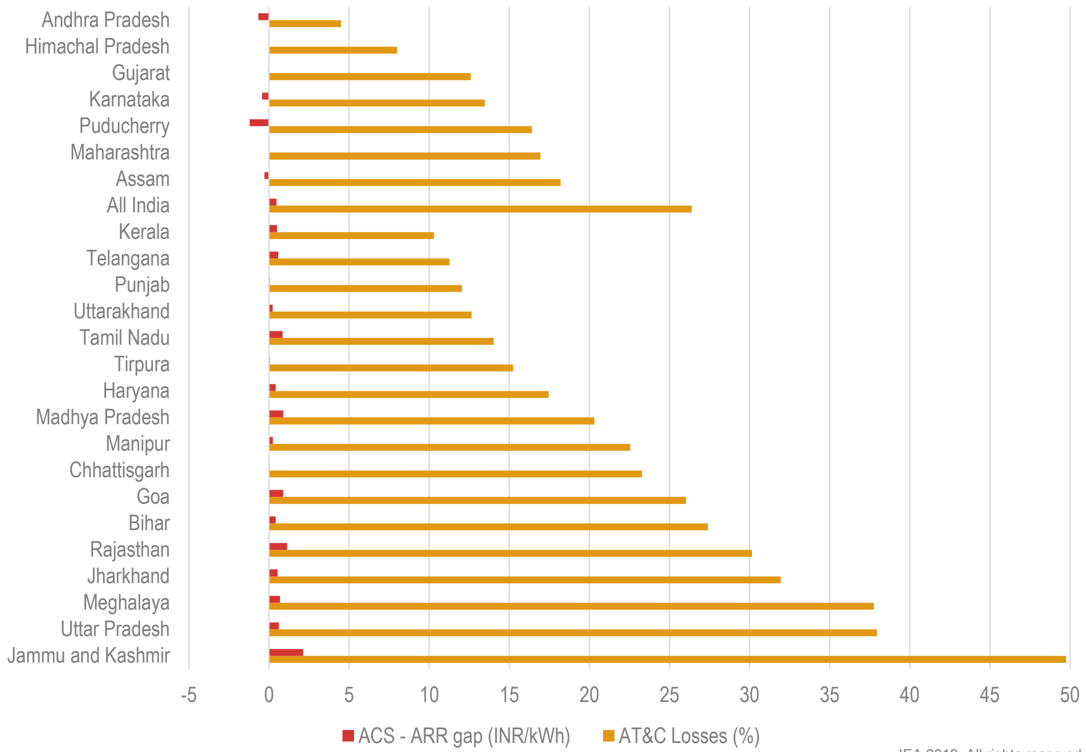
In 2017 the GoI amended the traditional coal allocation policy with a view to incentivising short-term power trading (see also Chapter 9 on coal). The Scheme for Harnessing and Allocating Koyla (Coal) Transparently in India (SHAKTI) was introduced. It provided for the auctioning of coal linkages for power assets that had PPAs, but no FSAs. The IPPs participating in the auction had to offer a discount on their PPAs. The goal of this scheme was to ensure supply to power plants, reduce the risk to the banks exposed to non-performing assets, reduce electricity bills and reduce imports. Since 2019 state-owned generators (e.g. NTPC) have been allowed to share their FSAs with private competitor generators.

The GoI constituted a High-Level Empowered Committee in July 2018 to address the issues of stressed thermal power projects, with a report delivered in November 2018 (HLEC, 2018). The GoI laid out the complex factors that led to the financial stress of the coal-based power plants, including coal supply issues, slower than expected growth in power demand, delayed payments by DISCOMs, borrowing limits for banks/financial institutions, aggressive tariffs quoted by bidders in competitive bidding processes, legal issues related to auctioning of the coal mines, regulatory and contractual disputes, inability of promoters to infuse equity, tardy implementation and other operational issues. The GoI constituted a group of ministers to examine the specific recommendations of the High-Level Empowered Committee. The ministers made a range of key recommendations for policy measures to solve stressed power projects, which were approved by the GoI:

- granting of linkage coal for short-term PPAs and allowing existing coal linkage to be used in case of termination of PPAs due to payment default by DISCOMs
- procurement of bulk power by a nodal agency against pre-declared linkages
- allowing central/state generators to act as an aggregator of power
- increasing in quantity of coal for special forward e-auction for power sector
- holding coal linkage auctions at regular intervals
- non-lapsing of short-term supplies of coal
- determining annual contracted quantity based on efficiency
- introducing the mandatory late payment surcharge for DISCOMs

Source: HLEC (2018), *Report of the High-Level Empowered Committee to Address the Issues of Stressed Thermal Power Projects*, https://powermin.nic.in/sites/default/files/webform/notices/20_Nov_R1_Draft_Report_HLEC_Final_20_Nov.pdf.

Figure 7.16 Performance of India's DISCOMs



Notes: ACS = average cost of supply; ATC = aggregate technical and commercial; ARR = average revenue realised.
Source: UDAY (2019), *Dashboard*, https://www.uday.gov.in/home.php.

The retail markets in India

Retail market rules and regulations

The Electricity Act of 2003 introduced the unbundling of transmission, generation and distribution and provided for wholesale and retail competition, where distribution/retail companies have the choice to purchase power from several generators. By law, electricity users above 1 MW are already free to choose their supplier; however, in practice most consumers are supplied by their local DISCOM. Open access means that DISCOMs have uncertainty of their load, as open access customers frequently switch between procuring power from the exchange or the DISCOM. Unbundling of supply and transmission has been carried out in all states. The last state was Jharkhand. Small and north-eastern states have carried out unbundling based on company size and commercial viability after their unbundling. India's DISCOMs combine generation and distribution activities. The 2014 amendment to the Electricity Act introduced the separation of carriage and content. International experience shows that the unbundling of retailing from generation and distribution (networks) is usually done at the functional or legal level, and less so at the ownership level. Notably, in small or rural supply areas the business case for the distribution system operator might be challenging without the retail business. Retail markets are mostly under the competence and regulation of state governments and the SERCs, notably with regard to the DISCOMs. The high level of non-payment and technical and commercial losses make it very challenging for DISCOMs to operate in a commercially viable manner.

Metering and smart meters

India's electricity distribution system suffers from a lack of adequate metering equipment, but innovation and investment in smart meters is on the rise. The GoI has developed several policy initiatives and programmes to promote smart metering and ensure that DISCOMs invest in meter and control equipment to enforce payment discipline:

- The National Smart Grid Mission was launched in March 2015 to create an institutional mechanism for planning, monitoring and implementing policies and programmes related to smart grid activities. The Bureau of Indian Standards published standards for smart metering (IS 16444 in August 2015 and IS 15959 Part 2 in February 2016). In August 2016 the CEA published the functional requirements for advanced metering infrastructure and technical specifications for smart meters.
- The 2016 Tariff Policy and the UDAY scheme mandate the deployment of smart meters for all consumers with consumption of more than 200 kWh per month.
- Energy Efficiency Services Limited has a Smart Meter National Programme that aims to replace 250 million conventional meters with smart meters across India by using bulk purchasing. The smart meters are to be installed over a period of three years. The programme is expected to improve billing efficiency by 75% to 100% while increasing the revenues of the utility companies (EESL, 2019).

Box 7.3 Principles of functioning retail markets

International experience suggests that empowering consumers and increasing their participation is critical to building transparent and competitive retail electricity markets, including:

- Cost-reflective pricing, with protection of vulnerable consumers addressed through targeted transfers that do not unduly distort efficient decisions.
- A competitive, dynamic retail market to encourage the development of innovative products and services that can harness demand response effectively and at least cost.
- Ready access to detailed real-time customer information, while ensuring privacy, to help stimulate competition, facilitate competitive entry, support the emergence of innovative business responses and improve customer choice.
- A knowledgeable and well-informed customer base that has the capability and opportunity to take full advantage of available choices.
- Market processes for metering, contracting, switching and billing that are as simple and seamless as possible to keep transaction costs to a minimum.
- Legal and regulatory governance frameworks that reduce uncertainty, establish clearly specified rights, responsibilities and obligations on contracting parties, promote greater harmonisation of standards and functionality specifications, and maximise scope for participation among potential service providers and customers.
- Enabling technologies that provide cost-effective real-time metering information, verification and control capability to support the introduction of real-time pricing, the development of a wider range of innovative demand response products and more effective customer choice.

The financial health of the DISCOMs

DISCOMs in India have high rates of losses, with aggregate technical and commercial (AT&C) losses amounting to 20% on average and 40% or higher in some states. In 2015 the central government made major efforts towards improving the financial health of India's DISCOMs under the UDAY scheme (Ujwal DISCOM Assurance Yojana). The UDAY is a financial restructuring plan or bailout scheme for DISCOMs by the GoI, which allows state governments (which own the DISCOMs) to take over 75% of their debt as of 30 September 2015 and pay back lenders by selling bonds. DISCOMs are expected to issue bonds for the remaining 25% of their debt. The Reserve Bank of India has issued guidelines for non-performing assets, which caps the exposure of DISCOMs to debt.

UDAY mandated the installation of smart meters in rural and urban areas, feeder segregation (separation of agriculture and power generation feeders) and the metering of transformers with the objective of cutting down losses to an average of 15% by March 2019. Progress in feeder segregation and smart metering remains low. Feeder separation data is only available for 17 states, of which only 6 states – Gujarat, Haryana, Punjab, Andhra Pradesh, Madhya Pradesh and Karnataka – have been able to achieve the 100% target.

According to the UDAY dashboard, almost all states and union territories have signed individual memorandums of understanding with the MoP, which include the obligation to make tariff revisions. In August 2019 AC&T losses stood at around 26% on average, but at almost 50% in some states (see Table 7.3), still above the 15% target. Compared to 2017, losses in fact rose in 2018. The gap between average cost of supply (ACS) and the average revenue realised (ARR) continues to be high in most states.

The agreed marginal tariff increases may not have been able to compensate fully for the increase in the ACS (seen between 2013 and 2016). The small reduction in the ACS–ARR gap can largely be attributed to the financial restructuring between 2016/17 and 2017/18, according to the Centre for Science and Environment (CSE, 2019). Based on an estimated interest component in the tariff of 8% of the total expense, the ACS fell, with the state governments taking over the debt and reducing DISCOMs' interest payments. CSE concludes that the gap closure is attributable to financial restructuring, not necessarily to the real progress of the UDAY scheme or the tariff policy (CSE, 2019). The new GoI announced further tightening of the UDAY scheme in 2020 through conditionality of grants and focusing on real loss reduction investments.

Table 7.3. Progress on DISCOM losses – UDAY scheme

Task Smart metering for consumers with:	**Stated deadline**	**Status as of August 2019**
> 200 kWh/month	December 2017	4%
> 500 kWh/month	December 2019	4%
LED distribution (UJALA)	March 2019	100%
Feeder metering	June 2016	100%
Feeder segregation		77%
Distribution transformer metering	June 2017	Rural 59%, urban 63%
AT&C losses down to 15%	March 2019	National AT&C losses: 26%
ACS–ARR gap down to INR 0/kWh	March 2019	National gap: INR 0.47/kWh

Source: UDAY (2019), Dashboard, https://www.uday.gov.in/home.php.

Tariff reforms

CERC regulates the tariffs for the central government-owned generators and the interstate generators. Generation tariffs are two-tier, including a capacity payment (availability-based tariff), which does not apply to renewable generators under PPAs.

Tariffs for retail supply and sale of electricity (both retail and wholesale) are determined by the SERCs. The latest tariff policy (competence of the MoP) was adopted in 2016, containing principles to guide the tariff-setting of SERCs:

- The simplified tariff structure is based on cost of supply of electricity (depending on voltage of supply, connected load and energy consumed) with classification on the basis of different voltage levels – low voltage, high voltage and extra high voltage. It is recommended that a maximum of five load categories be created for sanctioned load and connected voltage level, such as 0-2 kW, >2-5 kW, >5-10 kW, >10-25kW, and >25 kW for each voltage level. For each load bracket, the consumption slab may be further classified by usage, such as 0-200 units, 201-400 units, 401-800 units, 801-1200 and >1 200 units with progressive rates.
- Specific categories shall be maintained for domestic consumers below the poverty line and agricultural consumers so that the benefits of subsidy through Direct Benefit Transfer and cross-subsidy can be passed on to them in a focused manner.
- Consumption data based on primary usage – namely domestic, commercial, agriculture, institutional and industry – shall continue to be maintained. This data shall be useful as the basis for load forecasting, to analyse sensitivity to proposed actions and to give effect to programmes and policies including subsidies.
- No individual category/subcategory shall be prescribed for temporary supply. Such supply may be provided at a fixed multiple of cost of supply for that category.
- For consumers with suitable meters, time-of-day and two-part tariffs shall be introduced not later than 1 April 2020. This scheme should automatically be extended to other consumers as and when they get meters suitable for time-of-day and two-part tariff or single-part consumption-based tariff (for weaker parts of society).
- The fixed-charge tariff component should progressively over three years reflect the actual share of fixed costs in the revenue requirement of distribution licensees. SERCs may give an extension of up to two years for the reflection of fixed costs in the revenue requirement, for reasons to be recorded in writing. SERCs shall lay down a roadmap for this purpose.
- The process of merging existing categories/ subcategories and slabs shall be carried out progressively so as to achieve the simplified categorisation within a period of three years.
- The SERCs shall develop an appropriate framework to impel consumers to declare actual load, which comprises automatic revision of sanctioned load and imposition of penalty for exceeding the sanctioned load in the particular year. Thus the sanctioned load should at least be the maximum load registered during the previous 12 months.
- The SERCs may create a separate category for EV charging stations.

The 2018 amendment to the tariff policy requires all future power purchases to be procured competitively by distribution licensees and that DISCOMs are penalised for power cuts (see below in security of supply section). However, it provides for a series of exceptions in practice for state government or central government generators. While the new tariff policy will allow the passing through of legacy costs, it also allows central government generators and DISCOMs to choose not to sell power through the bidding process, thus limiting competition and hampering overall creation of a liquid and functioning wholesale electricity market, and leading to higher power prices for DISCOMs.

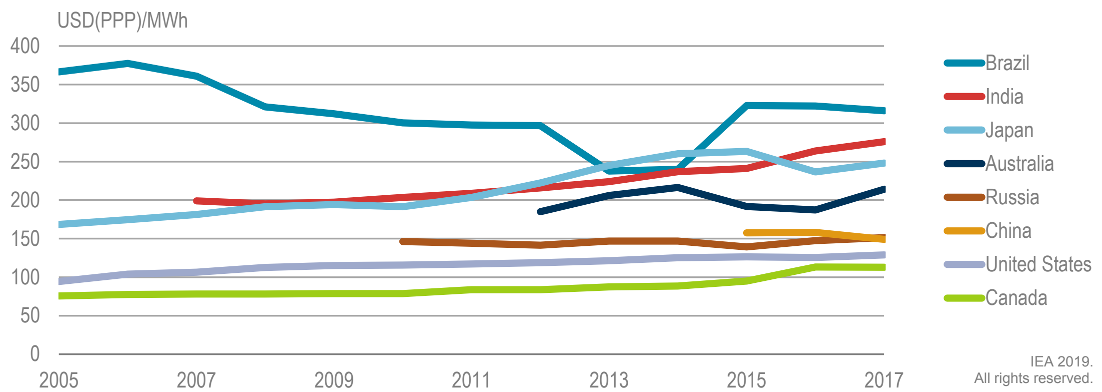
Electricity retail pricing

End-user prices in India are categorised by consumption group and there is a large variety of tariffs in each state, with cross-subsidy between industrial and residential users. DISCOMs have a two-tier tariff with a fixed cost component (operational and capital expenditure) and a variable cost component (fuel supply). Retail prices at state level show a wide range of tariff structures and methodologies, leading to a wide spread of categories. Table 7.4 shows average end-user prices in INR/kWh for the fiscal year 2015/16 for four types of customers: domestic, commercial (non-domestic), agricultural and industrial (average of both high-tension and low-tension type).

Agriculture (around 22% of total sales) is charged a flat tariff with a monthly fee and unmetered power for water pumping. As explained above, India is implementing a DISCOM programme to separate its agricultural feeders and to install meters, as well as to reduce technical losses.

India's residential retail electricity prices are among the highest in the world, if assessed by purchasing power parity (PPP) (in absolute terms they are very low). Only Brazil and Japan have more expensive power prices (Figure 7.17). However, the average electricity price paid by households is declining on a PPP basis.

Figure 7.17 Residential electricity prices in India and selected countries, 2007-15



Source: IEA (2018c), *World Energy Prices 2018*.

Table 7.4 Consumer average revenue per unit (INR/kwh), 2015/16

Region	State	Domestic avg.	Commercial avg.	Agricultural avg.	Industrial avg.
Eastern	Bihar	3.32	6.73	3.61	6.86
	Jharkhand	1.38	7.41	0.55	6.10
	Odissa	3.67	6.48	1.58	6.28
	Sikkim	2.64	4.94	0	5.96
	West Bengal	5.47	7.43	4.07	3.75
North-eastern	Arunachal Pradesh	3.78	4.91	0	3.85
	Assam	3.82	7.33	6.31	6.36
	Manipur	3.10	3.53	0.73	2.29
	Meghalaya	3.85	5.92	3.33	6.12
	Mizoram	3.60	6.63	2.00	6.19
	Nagaland	1.93	1.93	0	0.86
	Tripura	0	0	0	0
Northern	Delhi	6.40	11.60	3.82	10.2
	Haryana	5.60	7.69	0.34	7.36
	Himachal Pradesh	4.02	5.71	7.29	5.70
	Jammu & Kashmir	1.77	3.21	1.74	1.43
	Punjab	4.54	6.95	0	6.99
	Rajasthan	4.54	7.03	4.80	6.50
	Uttar Pradesh	3.62	9.22	1.63	8.35
	Uttarakhand	3.24	5.14	2.52	4.97
Southern	Andhra Pradesh	3.23	11.42	0.30	6.56
	Karnataka	4.43	8.34	0.98	6.68
	Kerala	3.76	12.73	2.29	6.83
	Puducherry	2.39	5.28	0.26	5.35
	Tamil Nadu	2.82	8.84	0	10.77
	Telangana	2.73	9.23	0.43	7.98
Western	Chattisgarh	3.71	4.89	3.76	7.09
	Goa	2.06	4.82	1.59	4.52
	Gujarat	5.15	5.65	2.67	6.88
	Madhya Pradesh	5.04	6.59	1.09	7.09
	Maharashtra	5.80	0	2.61	6.66

Note: avg. = average.

Source: Power Finance Corporation (2016), *The Performance of State Power Utilities for the Years 2013-14 to 2015-16*, www.pfcindia.com/DocumentRepository/ckfinder/files/Operations/Performance_Reports_of_State_Power_Utilities/1_ReportonhePerformanceofStatePowerUtilities2013-14to2015-16.pdf.

C. Ensure power system security

Reliability

The security of India's power system has been reinforced over the past decade thanks to the new grid code, scheduling and balancing mechanisms and the growing synchronisation of the grids. The reliability of the power system in India has improved, as illustrated in Figure 7.18.

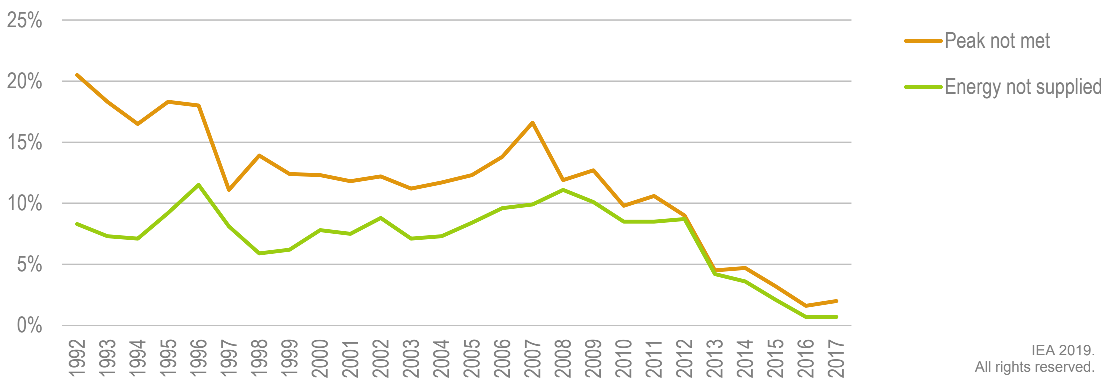
India has had frequent blackouts due to high frequency deviation (48-53 Hz [hertz]). In recent years the deviation has been more stabilised around 50 Hz, as illustrated in Figure 7.20. In 2013 full regional connectivity of the power system was achieved. The creation of a fully synchronised national grid across India's regions started in the 1990s.

In 2013 CERC updated the Indian Electricity Grid Code, which dated from 2006, and the deviation settlement mechanism and ancillary services mechanism. With the aim of maintaining grid frequency within a much narrower bandwidth of 49.5-50.3 Hz, CERC sends out warning signals at 49.7 Hz, introduced the concept of the controlled area, and imposes penalties on various state utilities for overdraw of power.

While much progress has taken place in the wholesale bulk power system, load-shedding continues and quality of supply remains low at the distribution and retail market levels.

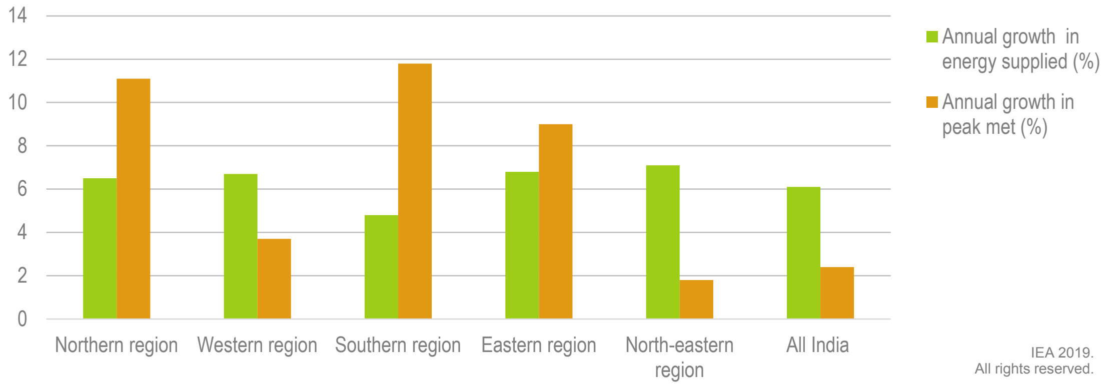
Lessons were learned from the historic blackout (see Box 7.3) that occurred during the summer of 2012 and affected more than 600 million people, mainly because of weak interregional connections and unbalanced periods of intense congestion.

Figure 7.18 Reliability of power generation, 1992-2017



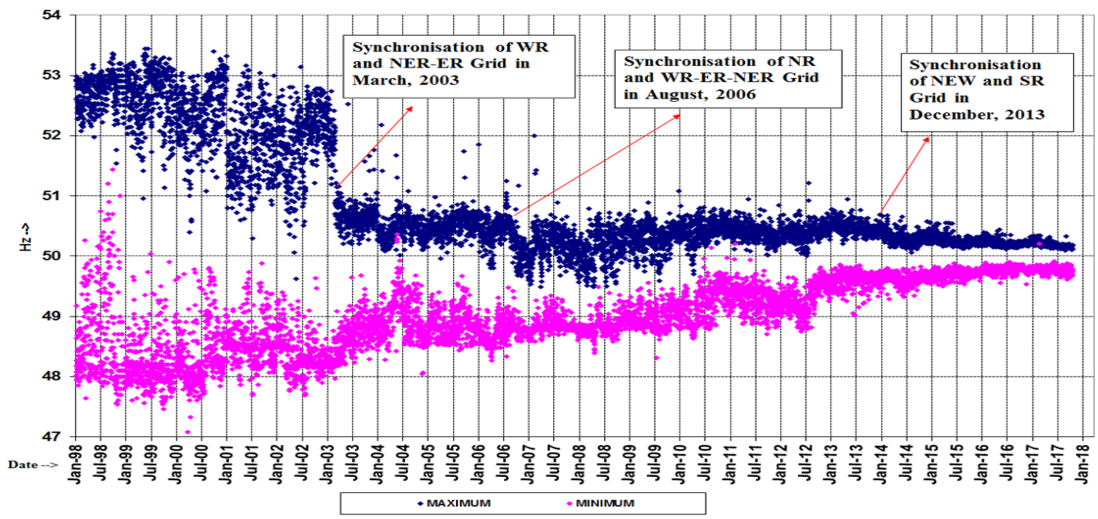
Source: CEA (2018a), *National Electricity Plan 2018,* www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf.

Figure 7.19 Reliability by region, 2017/18 versus 2016/17) (%)



Source: CEA (2018a), *National Electricity Plan 2018,* www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf.

Figure 7.20 Frequency deviation, 1998-2018



Source: POSOCO, 2019.

Generation adequacy

According to the IEA, India's demand triples by 2040 to reach almost 3 700 TWh based on announced policies. Economic growth is expected to drive electricity demand, averaging 6.5% per year to 2040. And India's per capita electricity consumption remains one of the lowest in the world to 2040. As the traditional use of solid biomass declines, electricity sees its share in final energy demand increase from 18% today to 24% in 2040 (IEA, 2018c), notably from electrification and increasing cooling needs (see Box 7.5).

The main framework for adequacy planning is the 10-year National Electricity Plan, which is prepared by the CEA under the MoP every year for two 5-year periods (in total 10 years). The long-term demand projections are carried out by the CEA in the Electric Power Survey.

Box 7.4 The 2012 India blackout

In 2012 India experienced the largest blackout in its history, with two outages affecting nearly 350 million people and 670 million people, respectively, in 21 out of 28 Indian states, affecting a 3 500 kilometre-wide area stretching from the north to the east of the country.

The northern grid's high electricity demand (from agriculture) provoked strong power flows from western and eastern grids to the north, which had much lower loads than usual due to the monsoon. Power from the surplus western region had to flow through the central and eastern Indian states to reach the deficit northern region, as critical regional interlinkages were down due to planned and unplanned outages.

The outage started in the northern region grid due to a grid disturbance that occurred on 30 July 2012. However, on 31 July 2012 the northern grid collapsed for a second time, hours after the power supply had been restored, leading to the collapse of the northern, eastern and north-eastern regions. The eastern transmission lines also failed, disrupting power supply in Delhi, Uttar Pradesh, Haryana, West Bengal, Assam and Punjab, among other states.

CERC set up an inquiry committee after the blackout, which identified a number of critical issues, including states' failure to use under-frequency relays to curtail part of the load on the system, as state utilities preferred to use overdrawals or underdrawals of power from the system in a situation of depleted reliability margins (rather than purchasing private power generation or power from the organised markets). The absence of primary response from generators led to the excessive reliance on unscheduled interchanges rather than organised electricity markets. Besides, weak grid management and inadequate monitoring of the network added to insufficient visibility and situational awareness at SLDCs and the non-compliance of the SLDCs with the instructions of the RLDCs, leading to a lack of co-ordinated outage planning and inadequate appreciation of transfer capability vis-à-vis transmission capacity.

The inquiry report also found that restoration took a very long time. The Ministry of Power audited the transmission lines and concluded that emergency response should be ensured for essential services through dedicated island systems. Powergrid started work to develop stronger interstate and inter-regional links. In the aftermath of the 2012 blackout, the government adopted a number of regulatory measures towards the strengthening of ancillary services, including primary response (mandatory) and fast frequency response mechanisms to improve grid security and discipline. All regionally operating generators (around 70) are required to provide ancillary services.

Sources: CERC (2012a), Report on the Grid Disturbance on 30th July 2012 and Grid Disturbance on 31st July 2012, www.cercind.gov.in/2012/orders/Final_Report_Grid_Disturbance.pdf?source=post_page; CERC (2012b), Report of the Enquiry Committee on Grid Disturbance in Northern Region on 30th July 2012 and in Northern, Eastern & North-Eastern Region on 31 July 2012, https://powermin.nic.in/sites/default/files/uploads/GRID_ENQ_REP_16_8_12.pdf?source=post_page.

Box 7.5 Cooling demand

Cooling systems are also a major driver of increasing electricity demand. The number of households in India owning an air conditioner has increased by 50% in the last five years to reach 4.5% in 2017. The IEA expects this share to rise to 31% by 2030, and by 2040 two-thirds of households in India are projected to own an air conditioning unit, a 15-fold increase from today. Air conditioner performance will significantly shape overall electricity demand in buildings. A similar pattern is apparent in the commercial sector. Minimum performance standards are not keeping up with market developments. Without major improvements in air conditioner performance, electricity demand for space cooling in buildings in India will increase by as much as 700% over current levels by 2040, reaching nearly 800 TWh in 2040, or more than all the electricity consumed in buildings in both India and Indonesia today. About 70% of that growth is expected to come from the residential sector (many offices, shops, hospitals and public buildings already have air conditioning). This will have particular implications for electricity networks, since residential cooling demand tends to peak when the sun has gone down and solar electricity production diminishes.

Source: IEA (2018d), *The Future of Cooling*.

With a total peak demand of 170 GW and installed capacity of 350 GW in 2017, India had a large reserve margin with overcapacity. In recent years India's power system has had comfortable reserve margins, also because demand has been lower than expected. Accordingly, the amount of energy not supplied and the peak electricity demand-not-met has decreased steadily over the past decade (see Figure 7.18). The CEA estimates that India's electricity requirement (demand plus transmission and distribution losses) will reach 1 566 billion units (peak demand 226 GW) by 2021/22 and increase to more than 2 047 billion units in 2026/27 (peak demand 299 GW), requiring an investment in capacity additions of more than USD 304 billion (CEA, 2018a). By 2029/30 the CEA expects 2 325 billion units of demand and a peak of 340 GW, which is double today's peak demand.

In India the evening peaks are higher than the morning peaks and peak load usually occurs in the month of October. Future electricity demand is expected to be very different, with high peak demand much more linked to cooling needs and stress in the evening peaks when the contribution from solar power is low.

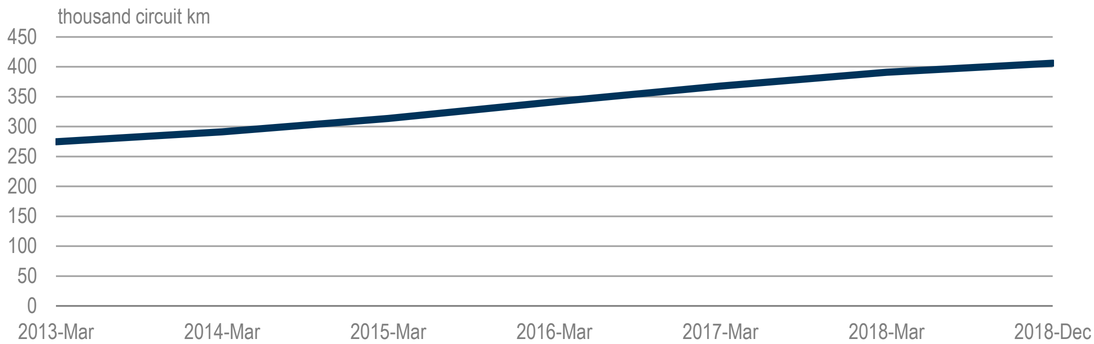
Network adequacy

By the end of 2017, India had total inter-regional transmission capacity to transfer nearly 75 050 MW. By 2022, this will increase to 1 18050 MW and Powergrid estimates it will be adequate to meet the energy flow requirements across the regions within India.

Annual additions of transmission lines remained robust over the past decade, as illustrated in Figure 7.21. The National Electricity Plan envisages the addition of 126 000 circuit kilometres of power lines and 463 000 MVA of transformation capacity (220 kV and above) by 2027, with a view to helping the integration of 175 GW of renewable energy. Since 2012, the volume of congestion has been reduced from 11% in 2011/12 to 0.4% in 2017/18 (IEX, 2018). However, investment in intrastate transmission lines has been slower than the construction of interstate lines due to permitting and land acquisition delays (see the detailed assessment in Chapter 8 on system integration).

Network investment, notably at distribution levels, has been a high priority for the government, with a view to ensure access to electricity. In addition, the Ministry of New and Renewable Energy and the Power Grid Corporation of India developed the Green Energy Corridors. The corridors include interstate and intrastate networks to integrate the additional 40 GW of renewable energy by 2020 (first phase), notably from the variable renewables-rich states of Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh and Rajasthan. Total costs were estimated at USD 7 billion. The integration of the new renewable target of 175 GW will require a second phase of the Green Energy Corridors.

Figure 7.21 Annual completion of new transmission lines



Source: CEA (2018a), *National Electricity Plan 2018*, www.cea.nic.in/reports/committee/nep/nep_jan_2018.pdf.

Quality of supply

In the light of high transmission and distribution losses, growing electrification and the poor financial health of the DISCOMs, India's residential electricity supply still has a high number of power outages. A recent study using satellite images found that the extension of the electricity grid during 2005-12 may have actually led to a higher intensity of power outages in the period after 2013 (World Bank, 2019). No reliable data are available as India's DISCOMs are not obliged to measure supply disruptions. The Indian Human Development Survey collects information on the reliability of supply. In 2011/12, 45% of the rural population had power outages of around 13 hours a day (World Bank, 2019).

The DISCOMs are under scrutiny for the delivery of electricity and quality of supply. They are required to ensure reliability and quality of supply at all times – otherwise they can lose their licence. However, there is no monitoring in place, even if the SERCs have the legal right to remove licences.

At the same time, the state governments have signed memorandums of understanding with the MoP for the provision of 24/7 quality and reliable power by March 2022.

International experience confirms that clear performance standards and monitoring of quality of supply is best ensured through the so-called SAIDI/SAIFI indices (see Box 7.5).[6] SERCs have powers to set and monitor standards of performance of licensees; for instance the licensee has to pay compensation to consumers for failure to comply with the

[6] SAIDI = System Average Interruption Duration Index; SAIFI = System Average Interruption Frequency Index.

standards. SERCs also can induce quality of supply, notably through the introduction of performance-based regulations (operational efficiency through an availability-based tariff).

A model regulation on power quality was proposed by CERC for adoption by SERCs (an ongoing process).

Box 7.5 Monitoring and implementing quality of supply rules

Many countries' regulators are implementing SAIDI and SAIFI indices with a view to guiding operators towards more reliable distribution network operations. Under quality of supply, India's regulatory institutions are increasingly focusing beyond access to ensuring electricity is provided to subscribers at all times. As a measure of the reliability of electricity distribution, regulators and network operators calculate the number and length of interruptions to electricity distribution using international standards called SAIDI and SAIFI created by Institute of Electrical Electronics Engineers:

SAIDI (System Average Interruption Duration Index) – a system index of the average duration of interruption in the power supply indicated in minutes per customer.

SAIDI = total duration of interruptions for a group of customers/total number of all customers

SAIFI (System Average Interruption Frequency Index) – a system index of the average frequency of interruptions in power supply.

SAIFI = total number of interruptions for a group of customers/total number of all customers

These quality of supply indices provide regulators with the tools to assess the performance of network operators, establish a quality factor in revenue regulation, compare and benchmark their operations, and where necessary, demand that distribution network operators reimburse customers for long interruptions in electricity distribution. India's power sector has grown fast and most villages have gained access to electricity. The role of the distribution companies and the network is going to increase. Regulators therefore need a better system for assessing the performance of DISCOMs to achieve not only a reduction in technical and financial losses, and thus efficiency, transparency and open access, but also the quality and continuity of supply. The Forum of Regulators (FoR) has discussed with SERCs and the power industry the need for better monitoring, incentives and supervision of quality of supply. In August 2018 the FoR issued recommendations for state regulators and DISCOMs on how to the implement regulations on power quality across India (FoR, 2018).

An amendment to the Electricity Act is under consideration by the GoI, with a focus on the supply of reliable and quality power. In 2018 the GoI proposed amendments to the tariff policy, which are presently under consideration, with a basic framework for quality of supply:

- Continuity and reliability of supply: the consumer is entitled to have reliable supply of electricity on a 24/7 basis, provided they are not in default and have not been charged with any offence under the Electricity Act warranting disconnection. The 24-hour supply of adequate and uninterrupted power is to be ensured for all categories of consumer.
- Quality of supply: this shall be measured as per standards prescribed by the CEA.
- Application for connection, disconnection, enhancement or reduction of connected load: these must be responded to and completed within a reasonable time frame.
- Complaints of supply disruption: these must be responded within the stipulated time frame barring major breakdown or force majeure.
- Failure to meet standards: in this instance, penalties may be imposed on licensees in accordance with section 57 of the act.
- Power cuts: In case of power cuts other than in force majeure conditions or technical faults, an appropriate penalty as determined by the SERC shall be levied on the DISCOM and credited to the account of the respective consumers. The level of the penalty shall be laid down by the respective SERC through regulations.

Flexibility of the power system

India's power system will need to accommodate the targeted 175 GW of renewable energy by 2022, 275 GW by 2027 and the 450 GW thereafter. This will require measures to ensure system integration and improve the financial viability of the power sector. Regional grid integration is advancing, but at a very slow pace, which is due to political economy, lack of financing, potential loss of revenue for incumbent generators and competition concerns. These concerns are common across regional electricity markets and systems around the world.

Coal remains the primary source of reliability in the power mix (with 200 GW out of a total of 356 GW installed capacity) besides hydropower, whose share is expected to decline in the next decade by 30% due to climate change impacts (CEA, 2018a). Following changes introduced by the CERC in 2017, the coal fleet is mandated to run at a minimum of 55% for interstate generating plants (previously above 70%), which makes its contribution to flexibility rather limited. The IEA has worked with the MoP and MNRE on actions to foster power plant flexibility, notably of the coal-powered fleet. Efforts are being pursued at a state or regional level to reduce the need for flexibility of the system, by smoothing the peak demand periods or by better forecasting and dispatching.

India has large potential for demand-side management. The IEA *World Energy Outlook 2016* estimated that almost a third of India's electricity demand could be shifted in the summer (June to August), while the high share of variable renewables in the winter limits such options during December to February. This is particularly true for agricultural demand. Several states already plan to shift agricultural consumption to the daytime by adjusting preferential monsoon and night-time tariffs. As electricity consumers are used to frequent power supply cuts and interruptions, their price and supply elasticity is much higher than in other countries and by international comparison. India has very good conditions for demand response from industrial, commercial and household consumers.

India expects growth of wind and solar PV to reach a share in total installed capacity of 36% by 2030, and flexibility needs will therefore significantly increase. The system integration of solar PV will require investment in storage and distribution networks and ramping capability to cope with the "duck curve" in the morning and evening hours. Wind integration requires transmission and balancing capacity to keep up with wind power's strong seasonality. Better regional interconnections across India's regions and more flexible power plants besides storage are critical. Hydro generation is at a maximum in the month of July, as is wind power, which therefore limits the way these sources can complement each other. Chapter 8 on system integration focuses on key sources of flexibility, that is interconnections, demand-side response, storage and power plant flexibility.

Assessment

In 20119 India had installed power generation capacity of 366 GW,[7] with coal-fired generation (204 GW), solar (33 GW) and wind (37 GW), followed by hydro (50 GW) and natural gas (25 GW). Grid-connected solar PV has been growing particularly quickly, with around 25 GW added alone during 2013-18. Biomass accounts for10 GW and small hydro for 4.5 GW. It is coal power that continues to dominate the generation mix with a contribution of 74%, followed by hydro at 9.3% and natural gas at 4.6% in 2017.

Peak electricity demand in India stood at approximately 165 GW in 2017, but recent data suggests that peak demand surpassed 180 GW in late 2018. Unavailability due to the age and low efficiency of the plants aside, this margin indicates a considerable amount of surplus in the dispatchable capacity.[8] Demand has been growing more slowly than anticipated in recent years at an annual average of 5%, notably below expectations in the industrial sector. Loads are expected to grow in the residential segment, driven by cooling demand as well as to some degree by increased access to electricity.

India has made remarkable progress in connecting its citizens to the electricity grid in recent years. In 2018 the GoI announced that all villages had been electrified, and that all households had reached full electricity access in March 2019. States that have traditionally featured the lowest levels of electricity access in the country (like Bihar, Assam, Orissa or Uttar Pradesh) have made substantial progress in their efforts to roll out electricity access. This development can only be commended and is an important step to remove the shackles of poverty from hundreds of millions of people, not least women and children. This will enable increased economic productivity, growth and bring modern-day comforts to the entire country.

However, connection to the electricity grid is not identical to around-the-clock supply. Notably, the power system has been marred with frequent load shedding for decades, and while interruptions are going down, they are still a normal part of life for many citizens. The GoI has set a target of providing 24/7 access to electricity across the country. However, reaching this objective requires action at the state level. States control electricity distribution and supply via the predominantly state-owned DISCOMs.

India has largely focused on the adequacy of power generation to meet peak demand and ensuring adequate fuel supply, with energy planning under the CEA, in particular via the

[7] Excluding captive producers.

[8] There is a substantial number of so-called central-level plants, where multiple states have a right to receive a share of the generated electricity and pay a proportionate share of the costs (in total of 84.5 GW, of which 57 GW are coal, 12 GW are hydro and 7.2 GW are natural gas).

National Electricity Plan, drafted by the CEA and prepared under the aegis of the MoP and in consultation with POSOCO, state governments, CERC, NITI Aayog and various other stakeholders. The power system in India is in transformation and most growth is expected to come from solar PV, most of it located behind the meter and not visible to system planners and dispatchers.

To improve its assessment of adequacy, India will need to consider energy efficiency impacts in energy system planning. The National Electricity Plan would benefit from better demand data (which would stem from the scale-up of smart meter roll-out coupled with data management and analytics). Moreover, transmission planning in India is not yet carried out to ensure network adequacy for the new ambitious renewable target of 450 GW and expected contributions from battery storage, reflecting the need to consider the mix of different stakeholders at the state level, private/public utilities and merchant investors.

The apparent contradiction between ample generation capacity and unmet demand points to the core challenge of the Indian power sector: the financial viability of its DISCOMs. Retail electricity tariffs are heavily subsidised by state governments, as well as via cross-subsidies from industrial and commercial sectors to residential consumers. Revenues are further challenged by very high losses. AT&C losses in India average approximately 20% and vary across a wide range (up to 50% in some states) according to recent government data. Compared to many other countries, commercial losses are very high. Most DISCOMs do not earn money by supplying residential customers, but rather accumulate losses by doing so. Interruption of supply to such consumers is thus one of the tools that DISCOMs have available to reduce their financial losses. These practices have cemented a low quality of supply, which in turn has created an expectation on the side of customers that they should pay very little for electricity – or nothing at all. This feedback loop and subsidy trap is a core reason behind the stubbornly high AT&C losses in many states.

Being a hotly debated topic for decades, the government has taken steps to tackle this situation, most recently in 2015 via implementing a reform package known as the UDAY scheme. The core idea of this scheme is to transfer 75% of the DISCOMs' debt, which stood at USD 60 billion (INR 4.3 trillion) in financial year 2014/15, to the states. In turn, DISCOMs are committed to more stringent enforcement of metering, accounting, billing and revenue collection in order to cut AT&C losses and improve revenue. In addition, a target was set that electricity tariffs could only be set within a band of +/- 20% of the average cost of supply – any tariff below this band would have to be paid for by the states to the DISCOMs. The scheme has had some successes, but many DISCOMs still run substantial losses, and while metering has improved, the collected revenues often remain well below the cost of supply. In fact, the GoI has announced measures to ensure future conditionality of loans to DISCOMs based on achievement of actual loss reductions.

In contrast to the residential sector, commercial and industrial customers are financially attractive for DISCOMs since they pay higher tariffs covering not only the cost of supply, but also a cross-subsidy to offset part of the losses incurred in the residential sector. However, the comparably low reliability of electricity supply has triggered the widespread adoption of back-up power solutions and captive generation in these segments. There is substantial uncertainty over demand for DISCOMs and other system operators, as industrial clients are increasingly deciding to purchase power via open access or choose autoproduction (captive plants), while sometimes, however, switching back to DISCOMs.

Agriculture is a large burden for DISCOMs, too, as they cannot cover their costs. Electricity needs in agriculture are primarily driven by water pumping. Because pumps can be operated with a degree of flexibility across the day, this consumption is highly flexible and can match the availability of solar output and water needs. But still, in many states water pumping is done during the night-time and could be shifted to the daytime when there is greater solar PV penetration. Separating agricultural feeders from the rest of the grid and supplying agriculture directly with solar PV can dramatically reduce supply costs for DISCOMs, hence reducing losses while also boosting variable renewable energy generation.

For energy-intensive industries, captive subcritical coal plants have been the option of choice, with total capacity at 80 GW (68% of all captive plants are larger than 1 MW) in 2017. The number of back-up generators running on diesel is even higher than this, with estimates around 140 GW. While these options can provide commercial and industrial consumers with the required reliability, they come at a very high cost, especially if relying on diesel. Assuming a diesel price of USD 1/litre, per-kWh costs are in the range of USD 0.25-0.30/kWh. Triggered by the high price of diesel for back-up power for small-scale captive applications, solar PV has emerged as a cost-effective option for offsetting grid-based electricity for smaller industrial and commercial customers. Combined with batteries, this option not only helps reduce electricity bills, but can also guarantee reliable supply. The widespread adoption of such options poses an additional financial risk for DISCOMs, but it could also be an opportunity for adding flexibility to the power system if electricity tariffs are reformed (see Chapter 8 on system integration).

The general insufficiency of revenue and non-cost-reflective tariffs are among the major challenges. Reform of tariff structures – while politically challenging to implement – are ultimately required to ensure the long-term functioning of the sector. Additional steps need to be taken to ensure the efficiency of retail markets by improved metering, accounting, scheduling, billing and revenue collection at state level. The push for advanced technologies such as smart meters can help reduce AT&C losses, increase the efficiency of the system and provide for the adoption of innovative approaches to targeted subsidy payment to protect certain segments of customer. In addition, further reforming the DISCOMs through the unbundling of grid and retail business, i.e. separation of carriage and content, can open up improved operations in the grid and the financial viability of both segments. In order to continue to move towards open access and enabling customers to choose their supplier, fair and transparent access to the grid is crucial.

The poor financial position of DISCOMs also has repercussions at the wholesale level. Wholesale markets in India are currently dominated by long-term PPAs between generators and DISCOMs. DISCOMs pay an ABT that recovers capital and fixed costs (capacity payment) independent of the plants' use, and a variable cost depending on its dispatch (fuel cost payment). Around 90% of all the electricity supply in India is covered by such agreements. As frequency deviation is no longer a real issue, the ABT may no longer be compatible with the power system in India.

While the ABT was successful in fostering India's power availability and investment, the way it has interacted with the wholesale market has now become a major source of inefficiency and overcapacity. These contracts have been interpreted as physical contracts, without the possibility of taking advantage of cheaper surplus energy to be purchased from other generators or even from other DISCOMs. Combined with problems of fuel supply, this has created a situation in which inefficient and polluting generators can have higher utilisation than newer and more efficient plants. The vision of CERC and its proposal on the creation of a market-based economic dispatch addresses these concerns and could help improve the economic efficiency of the system.

The poor financial position of DISCOMs translates into payment delays to generators. Indeed, approximately 40 GW of coal capacity and 25 GW of gas-fired capacity has been considered a stressed asset, due to lower than expected demand and utilisation, and payment delays from DISCOMs. One crucial measure to alleviate this situation is the retirement of old, inefficient capacity. Notably, the MoP has identified approximately 20 GW of old capacity that will be retired over the coming years, adding to 8 GW of retirements that have occurred over the past five years. While such measures bring important benefits also from an environmental perspective, they are not sufficient. What is needed is a more comprehensive reform of wholesale electricity markets.

Reforming wholesale markets with a view to enhancing operational efficiency is a priority, against the background of rising shares of variable generation. Today 90% of electricity is traded in the form of highly inflexible PPAs and the vast majority of interstate transmission capacity is reserved under long-term agreements. Boosting the liquidity on day-ahead and intraday markets, as well as establishing real-time/balancing markets and ancillary services markets, should be priority areas for regulatory action. Finally, mechanisms for unlocking more efficient use of interstate transmission and managing congestion are needed.

While the possible benefits from introducing comprehensive wholesale market reforms have been laid out, notably by CERC, it will not be easy to implement such comprehensive reforms in India's complex energy governance structure. In this context, wider awareness of the possible benefits of such reforms – both for consumers (via reduced costs for DISCOMs to buy power on wholesale markets) as well as investors and owners of stressed assets (via increased utilisation) – will be key.

Apart from supply-side reforms, the demand side will be of paramount importance for the future of the Indian electricity system, as load is expected to double up to 2030. A large proportion of this will come from buildings, in particular for space cooling. The demand side will also be critical for improved integration of renewable energy (see section on system integration).

The DISCOM governance model needs to be restructured. Governance needs to be improved through appropriate monitoring, control and financial oversight. At the retail tariff level, greater rationalisation is critical with a tariff system that allows all market participants, industrial, commercial or residential participants to purchase electricity. DISCOMs need to be required to perform in accordance with public policy objectives, thus ensuring quality of supply, investing in metering and smart grids, making infrastructure upgrades such as feeder separation, and undertaking detailed data collection and analysis.

While smart meters do not directly result in end-use energy savings, they can enhance or enable savings opportunities by providing consumers with actionable information about their energy consumption. Smart meter data can also be used to validate efficiency project savings. However, smart meter deployment has been very slow, despite legal requirements and monitoring under the GoI UDAY scheme. Enacting a broad set of standards for power quality can be a cost-effective way of improving the performance of the grid and avoiding costly interruptions in electricity supply, especially for industry. Power quality issues are not necessarily linked only to voltage interruptions, but also relate to large frequency variations (e.g. from flicker and harmonics). Power quality issues can lead to increased system and economic losses in output and equipment to industry – further deterring industry from staying grid-connected. The FoR and the CERC have recognised these problems and propose model regulation in order to implement further power quality standards at state level.

Recommendations

The Government of India should:

Wholesale electricity

- Support the implementation of a comprehensive reform of wholesale markets that would allow India to minimise the costs of electricity supply, making the best use of all existing assets, including captives and new variable renewable resources, and that would include:
  - liquid day-ahead and real-time markets that ensure countrywide economic dispatch and efficient use of transmission grid capacities
  - system services markets that are open to innovative providers, including demand-side response, aggregators and storage
  - co-ordinated transmission planning across India, including intrastate transmission needs involving the multitude of relevant stakeholders.

Retail electricity

- Implement cost-reflective tariffs and provide clear guidance on the conditions for the simplification and rationalisation of retail tariffs by the states. This will require a comprehensive approach, including incentives for compliance, public awareness campaigns on the benefits of tariff reform and consumer engagement.
- Mandate the adoption of metering, accounting, billing and revenue collection by DISCOMs and ensure strong supervision by state-level regulators.
- Continue to promote the reduction of subsidies in tariff policy by moving to targeted subsidy payment to protect certain segments of customers.
- Promote the implementation of a reform agenda in the DISCOMs by fostering the unbundling of grid and retail business activities to improve grid operations and the financial viability of both segments.
- Encourage the implementation, monitoring and compliance of a broad set of power quality norms and standards (SAIDI/SAIFI) at state level, through state regulators, in order to cost-effectively reduce supply disruptions to households and industry and their associated economic losses.

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8. System integration of variable renewable energy

Key data

VRE installed capacity (2018*): 64 GW, of which wind 35 GW (9.9% of total installed power capacity), solar PV 28 GW (7.9% of total installed power capacity)

VRE generation (2018): wind 62 TWh (5% of total electricity generation), solar PV 39 TWh (3% of total electricity generation)

Local hotspots: VRE-rich states

Wind leaders: states of Rajasthan, Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat, Maharashtra and Madhya Pradesh with a total of 35 GW (99% of total installed wind capacity) and 61 TWh (99% of total wind generation)

Solar leaders: states of Rajasthan, Tamil Nadu, Andhra Pradesh, Telangana, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh and Punjab with a total of 26 GW (94% of total installed solar capacity) and 36 TWh (93% of total solar generation)

*India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. The statement: "VRE installed capacity (2018)" refers to the data from 1 April 2018 to 31 March 2019.

Data sources: MNRE for wind and solar installed capacity and CEA for wind and solar generation.

Overview

As of 2018 India achieved 8% wind and solar generation in its power system, double the share of 4% in 2016. India is therefore in Phase 2 of the International Energy Agency (IEA) Framework for System Integration of Renewables. At the state level, the country's power system is a very diverse picture. Five states (Karnataka, Tamil Nadu, Rajasthan, Andhra Pradesh and Gujarat) are already facing significant system integration challenges, with solar and wind shares above 15%. In the future, the IEA expects more Indian states to experience ever higher shares of variable renewables. While moving towards a cleaner energy mix, this may create new challenges and those states will be required to make significant changes to how they operate their power systems.

At the same time, the need for flexibility is increasing and can create the opportunity for growth and innovation at the national and state levels in India. Increasingly India will need to broaden the focus from power system flexibility coming from thermal plants (coal) to using all sources of flexibility (renewable power generators, grids, storage and the demand side), based on a thorough analysis of power system transformation and flexibility needs.

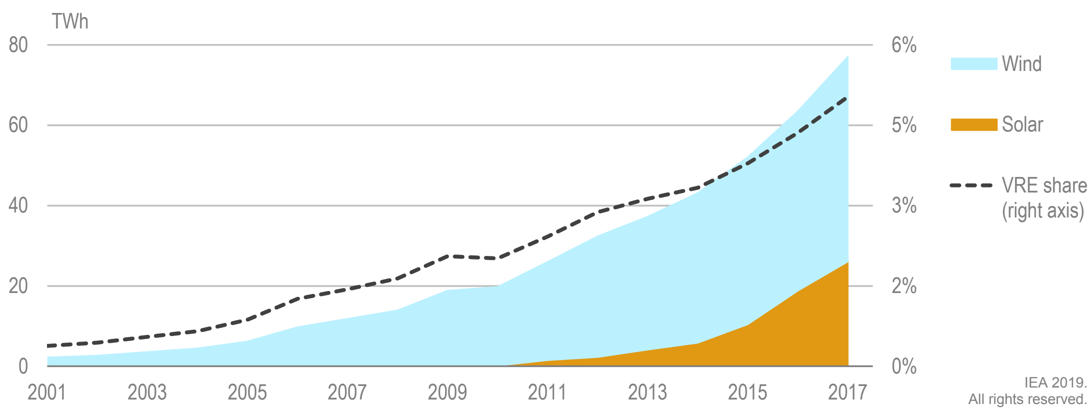
Advanced flexibility resources may include those provided by solar, wind and demand response, including from electric vehicles (EVs), battery storage, hydrogen and sector coupling.

India's complex power system structure, power markets and regulations require a vision for the system as a whole and milestones for a reform roadmap. The Government of India (GoI) aims to create a 2030 vision for power market reform and an optimal power mix, bringing together the central government, states, regulators and market participants. The existing Central Energy Regulatory Commission (CERC) proposals form a strong basis, but will require an extensive stakeholder engagement process for implementation, notably at state level.

Supply and demand trends

India has seen a rapid increase in electricity generation from variable renewable energy (VRE) in recent years (Figure 8.1). Wind power capacity started to increase in the early 2000s and has grown at an annual average rate of 17% in the last decade, according to IEA data. Generation from solar power has only recently started to grow. In the five years 2012-16, solar power production increased by 44% on average every year.

Figure 8.1 VRE electricity generation by source and by share of total generation, 2001-17

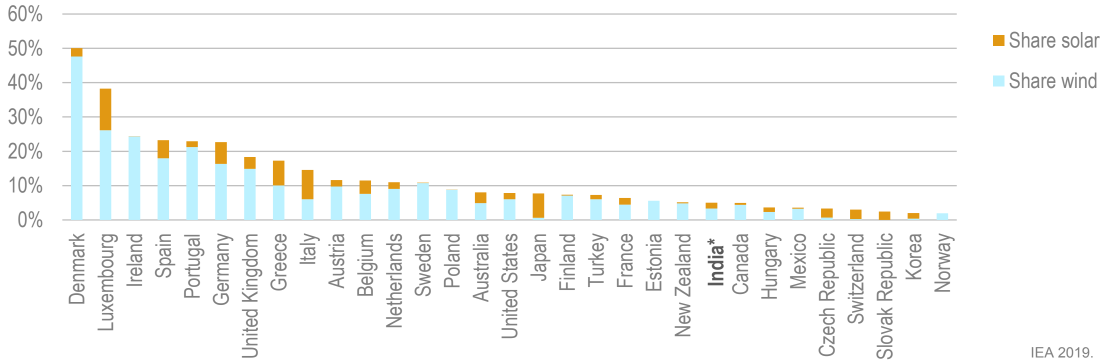


Wind and solar power generation have increased rapidly in recent years, together accounting for 5% of total electricity generation in 2017 and continue to grow towards India's 2022 target.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

In 2017 wind and solar power together accounted for 5% of total electricity generation. Compared to IEA member countries, this was at the low end of variable renewables in power generation (Figure 8.2). However, the share continues to increase as India pursues its ambitious targets for 100 GW of installed solar power and 60 GW of installed wind power by 2022.

Figure 8.2 Electricity generation from VRE sources as a percentage of all generation, India and IEA member countries, 2017



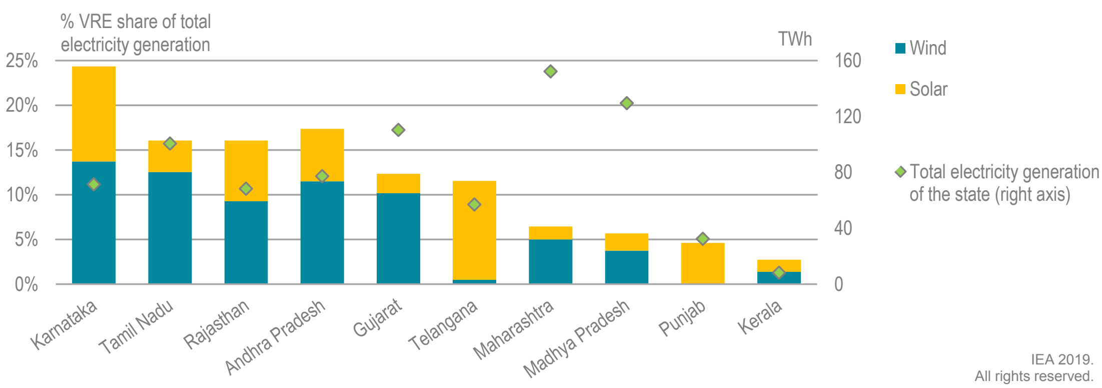
India has the eighth lowest share of VRE in electricity generation in an IEA comparison, with the potential for integrating more wind and solar in the grid.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Penetration of VRE at the state level

In 2018 VRE generation reached 101 TWh, accounting for 8% of the total electricity generation of the country (CEA, 2019d). In the states of Karnataka, Tamil Nadu, Rajasthan and Andhra Pradesh, VRE generation has already surpassed 15% of total electricity generation, mainly due to early wind deployment and lately solar (since 2016). In the states of Gujarat, Telangana, Maharashtra and Madhya Pradesh, VRE generation is between 5% and 15% of total electricity generation (left axis in Figure 8.3).

Figure 8.3 Electricity generation from VRE as a percentage of all generation in VRE-rich Indian states, 20118



Source: CEA (2019a), *Renewable Energy Generation Report, March 2019*, http://cea.nic.in/reports.html.

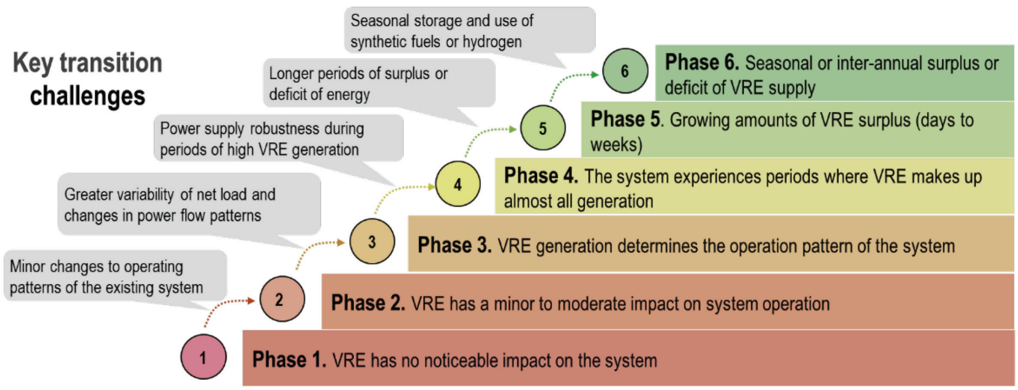
India's system integration challenges

The impact of and issues associated with the integration of VRE depend largely on its level of deployment and the context of the power system, such as the size of the system, its operational and market design, its regulation and its fundamentals of supply and demand. VRE generation can affect the planning and operation of the power system at all levels, from generation to transmission and distribution. Integrating VRE, particularly at higher shares, in a reliable and cost-effective manner requires different approaches compared to traditional power system planning and operation.

The IEA has developed a phased categorisation to capture the evolving impacts that VRE may have on power systems, as well as related integration issues. It categorises the integration of VRE into six different phases (see IEA and 21CPP [2018] for further details). This framework can be used to prioritise different measures to support system flexibility, identify relevant challenges and implement appropriate measures to support the system integration of VRE.

These phases also provide an assessment framework to understand current and future trends in system integration of renewables in India. Challenges depend on different phases of VRE deployment.[1]

Figure 8.4 Key characteristics and challenges in the different phases of system integration of VRE



Source: Adapted from IEA (2018a), *World Energy Outlook 2018*.

The main characteristics of different phases of VRE deployment are briefly described as follows (Figure 8.4) (IEA, 2017a, 2017b, 2017c):

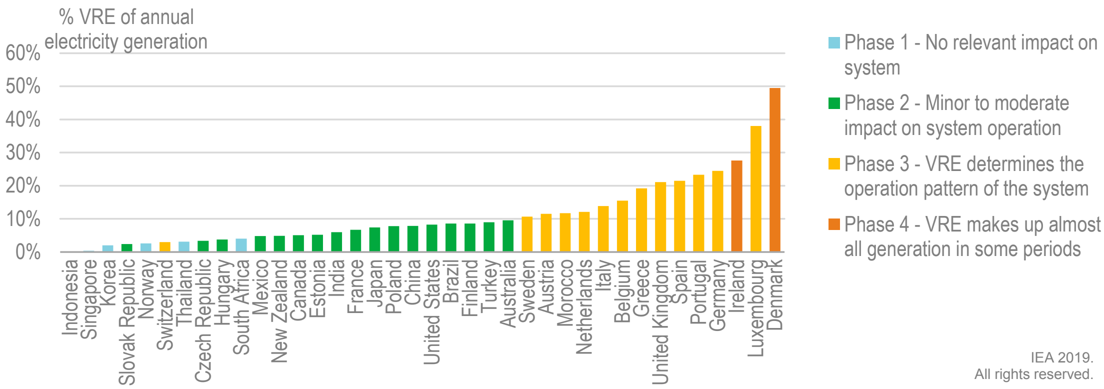
- Phase 1: The impact of VRE generation is essentially insignificant at the system level; integration effects are highly localised, for example at the grid connection point of plants.
- Phase 2: Differences between load and net load become noticeable. Upgrades to operating practices and making better use of existing power system flexibility resources are usually sufficient to achieve system integration.
- Phase 3: Greater swings in the supply–demand balance tend to require a degree of power system flexibility that goes beyond what can be fairly easily supplied by existing assets and operational practices.
- Phase 4: VRE output is sufficient to provide a large majority of electricity demand during certain periods (e.g. high VRE generation during periods of low demand); this requires changes to both operational and regulatory approaches to preserve power system stability.
- Phase 5: Without additional power system flexibility measures, adding more VRE plants in this phase may mean that aggregate VRE output frequently exceeds power demand and

[1] This section is derived from a discussion developed in IEA 2017a, 2017b, and 2017c.

structural surpluses of VRE appear. This leads to an increased risk of curtailment[2] of VRE output and could limit further deployment.

- Phase 6: Once this phase is reached, the remaining obstacle to achieving even higher shares of VRE becomes meeting demand during periods of low wind and sun availability over extended periods (e.g. weeks), as well as supplying uses that cannot be easily electrified. This phase can thus be characterised by the potential need for seasonal storage and use of synthetic fuels such as hydrogen.

Figure 8.5 Overview of VRE system integration phases for selected countries and regions, 2018



Countries around the world are at different levels of system integration. Regions within one country can be at a higher or lower phase than the national average.

Source: IEA (2019b), *Renewables 2019*.

It should be noted that the transition between phases does not occur abruptly from one to another. Rather, the phases are a conceptualisation intended to identify the main experiences. Issues related to flexibility will gradually emerge in Phase 2, before becoming the hallmark of Phase 3. In turn, certain issues related to system stability may already become apparent in Phase 3. The challenges faced by the power system are context-specific and depend not only on the share of VRE generation, but also on a number of other factors. These include the size of the system, the transmission infrastructure (including interconnectors), existing operational practices and existing levels of flexibility (for instance, access to hydropower and pumped hydropower facilities, and connection to heating networks). The IEA groups countries together to illustrate the different phases of system integration.

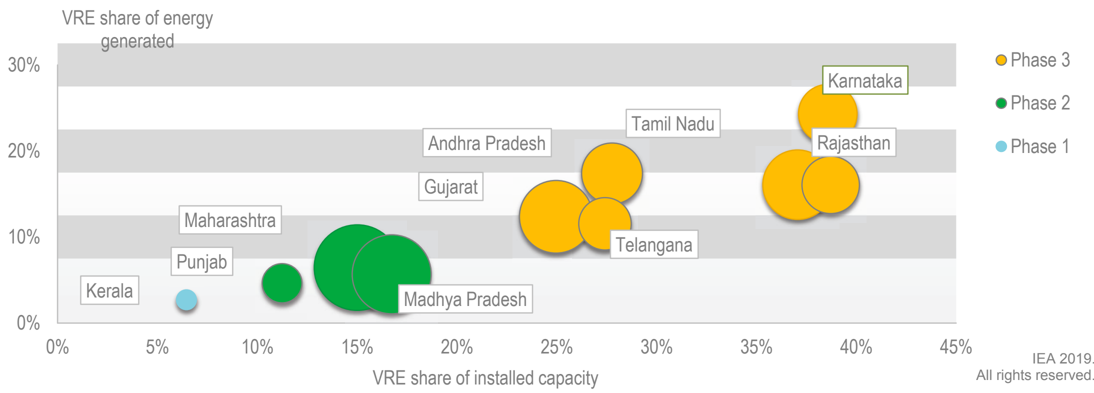
India as a whole can be classified as being in Phase 2 of system integration (Figure 8.5). However, at state level the Indian power system shows a very diverse picture, with many states already having much higher shares of renewable energy than the country's average. As shown in Figure 8.6, several Indian states are already facing significant system integration challenges characterised by Phase 3, while some are in Phase 2 and the majority are in Phase 1. The following section takes a closer look at the top ten Indian states with the highest levels of VRE generation (as a percentage of total generation) in 2018, often referred to as VRE-rich states.

[2] Curtailment is a reduction in the output of a generator from what it could otherwise produce given available resources.

These VRE-rich states (Figure 8.6) together accounted for 96% of VRE capacity deployment and 97% of total VRE generation in the country. Figure 8.6 shows installed VRE capacity as a percentage of total electricity capacity in each state (x-axis), VRE generation as a percentage of total electricity generation in each state (y-axis) and the phases of system integration. Table 8.1 highlights VRE capacity and generation data in renewables-rich states. Based on this analysis:

- six of the high VRE states are in Phase 3 (Tamil Nadu, Gujarat, Andhra Pradesh, Karnataka, Rajasthan and Telangana).
- three are in Phase 2 (Maharashtra, Madhya Pradesh and Punjab).
- all other states, including Kerala, are in Phase 1.

Figure 8.6 VRE share of installed capacity and annual generation, top 10 VRE generating states grouped by system integration phase, 2018



IEA 2019.

Note: The size of the bubble corresponds to the total electricity generated in the state.

Sources: CEA (2019a), *Renewable Energy Generation Report, March 2019*, http://cea.nic.in/reports.html (actual VRE electricity generation from April 2018-March 2019); MNRE (2019), *Total Installed Capacity*, https://mnre.gov.in/physical-progress-achievements (VRE installed capacity as of 31 March 2019).

The six states in Phase 3 (Tamil Nadu, Gujarat, Andhra Pradesh, Telangana, Karnataka and Rajasthan) are responsible for 78% of total VRE generation of India. They have a high VRE deployment as a share of total capacity (between 20% and 40%), but show relatively low VRE generation as a share of the total (between 10% and 25%). This is due to the low capacity factors of wind and solar compared to thermal generation, but it is also an indicator of curtailment of renewables due to power system flexibility problems, including frequency, voltage and inertia issues, as well as transmission bottlenecks.

In Phases 1 and 2, VRE has a minor to moderate impact on system operation; however, the importance of power system flexibility will increase significantly in Maharashtra, Madhya Pradesh and Punjab in the coming years as they transit into Phase 3.

Table 8.1 VRE capacity, generation and percentage share, VRE-rich states, 2018

States	Wind		Solar		% VRE share of total electricity generation
	Capacity (GW)	Generation (TWh)	Capacity (GW)	Generation (TWh)	
Karnataka	4.69	9.78	6.10	7.58	24.34
Tamil Nadu	8.97	12.60	2.58	3.55	16.07
Rajasthan	4.30	6.32	3.23	4.63	16.07
Andhra Pradesh	4.09	8.87	3.09	4.55	17.36
Gujarat	6.07	11.20	2.44	2.41	12.34
Telangana	0.13	0.27	3.59	6.30	11.53
Maharashtra	4.79	7.58	1.63	2.21	6.43
Madhya Pradesh	2.52	4.83	1.84	2.50	5.66
Punjab	0.00	0.00	0.91	1.49	4.61
Kerala	0.05	0.11	0.14	0.11	2.70
Total	35.61	61.56	25.55	35.33	

Sources: CEA (2019a), *Renewable Energy Generation Report, March 2019*, http://cea.nic.in/reports.html (actual VRE electricity generation from April 2018-March 2019); MNRE (2019), *Total Installed Capacity*, https://mnre.gov.in/physical-progress-achievements (VRE installed capacity as of 31 March 2019).

In Phase 3 states, VRE determines the operation of the system and flexible resources are needed for improved power system flexibility. In this phase, renewables forecasting and scheduling improvements, dispatch-balancing process review and other changes may be required alongside the activation of advanced flexibility resources, such as improved cross-border trade, storage and demand-side flexibility. Moreover, these states will be transitioning to Phase 4 in the coming years. Only a few parts of the world had reached Phase 4 by 2018, including Ireland, Denmark and South Australia. Their experience shows that a variety of sources of flexibility need to act together: ancillary services reform, the advanced activation of storage and demand-side resources, forecasting and scheduling, and flexibility requirements from VRE.

General considerations for system integration

System integration of renewable energy encompasses all the technical, institutional, policy and market design changes that are needed to enable the secure and cost-effective uptake of large amounts of renewable electricity in the system. The necessary adaptations are most significant for the integration of VRE technologies, namely wind and solar power.

The physical nature of electricity requires that generation and consumption are in balance at all times. System planning and operation need to ensure this, respecting the technical limitations of all system equipment under all credible operating conditions, including unexpected events, equipment failure and normal fluctuations in demand and supply.

The difficulty (or ease) of increasing the share of VRE in a power system depends on the interaction of two main factors: the properties of VRE generators; and the flexibility of the power system into which they are deployed (a more detailed discussion can be found in IEA [2014; 2016]).

Different timescales of system flexibility requirements

Power system flexibility is defined as the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring instantaneous stability of the power system to supporting long-term security of supply (IEA, 2018b; IEA, 2019c). Challenges for system integration and system flexibility can be categorised along different timescales:[3]

- In the **medium to long term** the key flexibility requirements relate to the availability of sufficient power system resources (generation, demand response, storage and imports from other areas of the grid) to reliably meet demand.
- In the **short term** the power system requires the ability to maintain the balance of supply and demand in the face of variability and uncertainty of both supply and demand. In order to achieve this, the power system needs sufficient flexible resources that can change their output quickly, at short notice and in a wide range from within a few minutes to several hours.
- In the **very short term** the power system needs to withstand disturbances from within the first milliseconds to several seconds following a load or generation change event, also referred to as stability.

Achieving high shares of wind and solar power in a cost-effective and reliable way

Given the broad impacts that high VRE shares can have, a comprehensive and systemic approach is the appropriate answer to system integration challenges. As identified by IEA analysis, a co-ordinated approach can significantly reduce integration costs and ensure electricity security (IEA, 2014; IEA, 2016). Achieving such a transformation requires strategic action in three main areas:

System-friendly deployment to maximise the net benefit of wind and solar power to the entire power system. This could, for example, mean prioritising VRE deployment with a greater contribution to peak load periods or locations close to load centres rather than focusing on VRE cost of production alone.

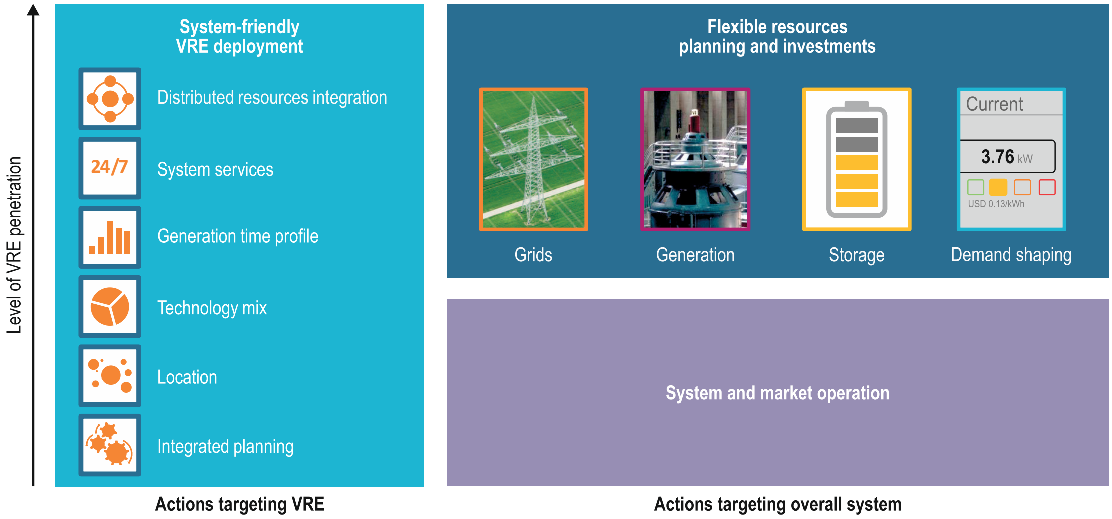
Improved operating strategies as a tool to maximise the contribution of existing assets and ensure security of supply. These include advanced renewable energy forecasting and enhanced scheduling of power plants. Where liberalised wholesale markets are in place, this may require an upgrade of market rules and products. In heavily regulated systems, action will need to target operational protocols and key performance indicators for system and power plant operators.

Investment in additional flexible resources. Even in concert, improved operations and system-friendly VRE deployment practices can be insufficient to manage very high shares of VRE in the long term. The point at which investment in additional flexible resources

[3] Based on detailed description in IEA (2018b).

becomes necessary depends on the system context. In all systems, however, an increase in flexible resources will become a cost-effective integration strategy at some point, requiring additional investment. Broadly speaking, resource adequacy and multi-hour flexibility issues have the largest economic impact. These can be addressed by systematic expansion of the grid, ensuring an appropriate power plant fleet and unlocking demand response potential and storage (Figure 8.7).

Figure 8.7 Integrating large shares of VRE requires system transformation



Source: Adapted from IEA (2014), *The Power of Transformation*.

Mobilising the contribution of each of the three areas requires putting in place appropriate market, policy and regulatory frameworks. Frequently it will also need a change in the roles of institutions in the power system, which can take time and resources to achieve. In a nutshell, a two-way adjustment is needed, with actions to make the overall power system more suitable for VRE generation and other measures to make VRE more suitable for the existing power system.

This chapter initially discusses the fundamentals that drive flexibility from the perspective of system and market operation in India, before turning to flexible resources and system-friendly VRE deployment, focusing on the four flexibility resources. At the end of the chapter, the IEA presents its flexibility analysis of India's power system, taking a longer term perspective up to 2040.

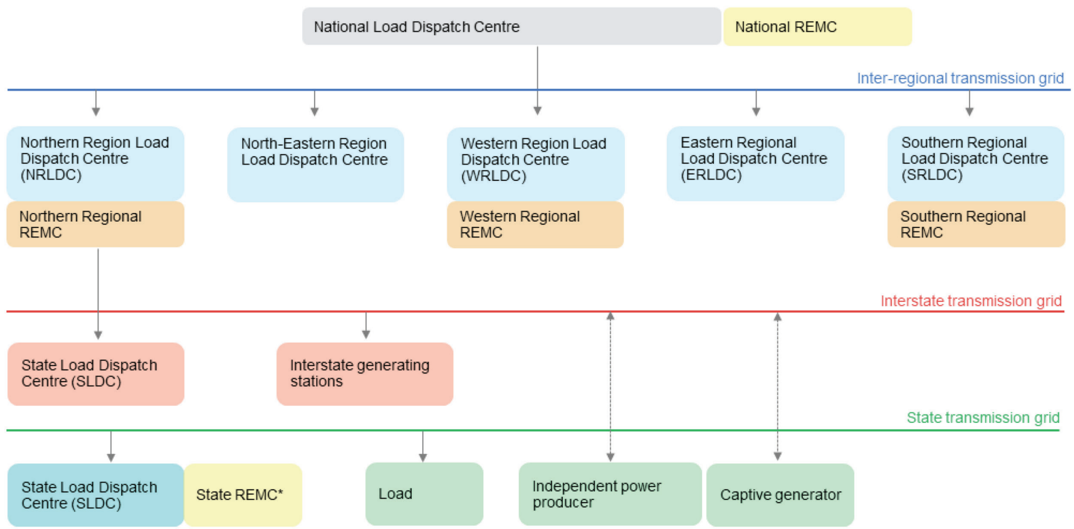
System operation and electricity markets

System operation – generation dispatch

India's power system is a large synchronous area that spans five regional grids. As such, responsibilities for system operation are entrusted to system operators at various levels: national (or central), regional and state levels.

Today's system operation is the result of the historic development of the system, from isolated power systems to state-wide grids and their regional interconnection, which allowed occasional exchange of surplus power. Since the 1980s the GoI has supported the gradual synchronisation and integration of the five regional grids. In 2013 the synchronisation of all regions into one synchronous grid was completed.

Figure 8.8 Structure of the power system operational structure



*State Regional Energy Management Centres (REMCs) for seven renewable energy-rich states of Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu.
Source: IEA, adapted from the Ministry of Power.

This historic grid and system is reflected in the operation of the system (Figure 8.8). Power System Operation Corporation (POSOCO) manages national and regional dispatch centres as the independent system operator at interstate level. Countrywide co-ordination and system operation is ensured via the National Load Dispatch Centre (NLDC). Each region has a Regional Load Dispatch Centre (RLDC), which operates the regional transmission grid and schedules the interstate generating stations of that region. A regional grid comprises a number of states. For example, the western regional grid has seven constituents: Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, Goa, Dadra-Nagar-Haveli and Daman-Diu. Each state then has its own State Load Dispatch Centre (SLDC). This structure implies that system operation is influenced by decisions at state, regional and national levels. Hence, to achieve a flexible system, close collaboration between the different levels is critical, while fully accommodating the specific requirements of each region and state.

The day-ahead scheduling process is aimed at optimal scheduling for dispatch the next day. The NLDC schedules and dispatches electricity across the interstate networks and optimises the dispatch of the RLDCs (it also manages electricity exchanges across borders). RLDCs co-ordinate this process for load and interstate generating stations, connected to the interstate transmission system. The SLDCs co-ordinate the day-ahead scheduling process for load and generators connected to intrastate transmission grids.

With decentralised scheduling, economic dispatch in India also follows a decentralised state-driven model. However, states and power distribution companies (DISCOMs) self-schedule the generators with whom they hold long-term contracts, not optimising state-level dispatch, while also not making use of cost-efficient unscheduled resources across

India. Generators can also revise their schedule to manage their real-time imbalances one hour ahead without any financial liability (right to recall) (CERC, 2018a). Against this background, the POSOCO consulted on the introduction of a national-level merit order-based dispatch (POSOCO, 2018) and CERC has proposed the creation of a centralised market for day-ahead scheduling and real-time dispatch with gate closure. Until 2010, renewables were exempt from scheduling, forecasting and management of imbalances.

System operation – forecasting of wind and solar output

Better forecasting of wind and solar generation is essential to help grid operators accommodate changes in wind and solar generation more efficiently and prepare for extreme events during which renewable generation is unusually high or low. Forecasts can help reduce the amount of fast response operating reserves needed for the system, thereby reducing the cost of balancing the system. Internationally, improvements have been made in recent years towards reducing mean forecast errors. Day-ahead forecasts support day-ahead decisions on whether generation capacity will be dispatched, driving operational efficiency and cost savings. Short-term forecasts determine the need for a quick-start generator, demand response, or other mitigating options to support reliable operation of the electricity system.

The penetration of wind and solar power in India's states remained below 10% until 2010 and grid integration was not seen as a serious issue. Indeed, VRE was exempt from forecasting, scheduling and supporting grid management with ancillary services. However, more recently CERC and the Forum of Regulators, POSOCO and the dispatch centres have taken several regulatory measures regarding VRE forecasting and management of ancillary services.

In 2010, under the Indian Electricity Grid Code, CERC put forward the Renewable Regulatory Fund mechanism, with the aim of requiring wind generators to undertake forecasting and provide their generation schedule on a day-ahead basis, while paying the deviation charge linked to grid frequency if their schedule deviates beyond a certain limit.

In August 2015 CERC proposed the Framework on Forecasting, Scheduling and Imbalance Handling for wind and solar generators connected to interstate transmission system as a substitute to previously unsuccessful Renewable Remuneration Fund, and amended the regulations under the Indian Electricity Grid Code and deviation settlement mechanism. The new framework applies to all renewable generators connected to the interstate transmission system with aggregate capacity of 50 MW and above, Ultra Mega Power Projects (UMPP) with a capacity of 500 MW, and expansions of existing renewable capacity below 50 MW, in line with the CERC transmission open access regulations (CERC, 2015).

The new framework adopts a hybrid approach to forecasting at the interconnection point with the transmission grid. The RLDCs carry out their own forecasts with the objective of securing grid operation, and the generators or pooling stations forecast their own needs. That means that regional wind and solar generators can use their own forecast or that prepared by the RLDC. However, the commercial impact due to deviation from the schedule will be fully borne by the generators themselves. As forecast errors decrease the closer it comes to actual generation, the wind and solar generators are provided with the option of 16 revisions to their submitted schedule (each revision for a duration of 1.5 hours during the day of actual dispatch).

Renewable Energy Management Centres

India is rolling out REMCs in the seven renewable energy-rich states of Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. REMCs will also be established in three RLDCs (north, west and south) and the NLDC to facilitate VRE integration along the Green Energy Corridors.

Table 8.2 REMC tools and functions

REMC component	Function
REMC SCADA Monitoring Tool	Real-time monitoring of renewable generation by collection of data from remote terminal units. Refresh rate of 2-4 seconds. State Energy Meter (SEM) data can be used in case remote terminal unit is not available.
Forecasting Tool	Collection of a) forecast data from forecast service providers and exchange of weather data with them, b) site-level actual renewable generation data from REMC SCADA tool, and c) weather forecasts, analysis and validation of accuracy of the forecast provided by individual renewables developers. Provide d) forecast to renewables developers not owning forecasting tool, and e) provide point-of-injection-level intraday and day-ahead data to REMC Scheduling Tool.
Scheduling Tool	Preparation of schedule from forecast received from Forecasting Tool. Co-ordinate with renewables developers to integrate their individually submitted schedule.
REMC Wide Area Measurement System	Data collection of critical substation via existing WAMS system in control centre.
Renewable Energy Control Reserve Monitoring Tool	Real-time analysis of reserves in own control area and in neighbouring area; scenario analysis for balancing renewable generation.

Source: Prayas Pune (2016).

The REMCs are to be equipped with advanced forecasting tools, smart dispatch solutions and real-time monitoring of renewable generation in their respective areas (Table 8.2). The proposed functionalities of the REMCs include: a) real time monitoring of all renewable generation at the pooling station level; b) intraday and day-ahead forecasting of renewable generation; c) co-ordination with corresponding load dispatch centres for scheduling and dispatch of renewable generation in its area of responsibility; d) co-ordination between corresponding load dispatch centres and renewable developers. The REMC at the national level will be responsible for monitoring renewable generation, analysing collected data and co-ordinating with load dispatch centres to maintain the security and stability of the system. The REMCs at the state level will have the additional responsibility of monitoring the operating reserves in the state. They will have five major tools as outlined in Table 8.2 (MNRE, 2015; GIZ, 2015).

The success of the REMC programme will depend on well-designed capacity-building programmes at all levels (including SLDCs and solar and wind producers). Software and hardware changes/upgrades may also be required at the SLDCs and by solar and wind generators in order to use the tools of the REMC programme. The state of Tamil Nadu – one of the pioneers of wind power deployment in India – implemented the REMC in 2016, which helped them to achieve a substantial reduction in wind power curtailment. Other states are on the path towards REMC implementation and require significant resources, including software, hardware updates and further support and capacity building to create well-functioning REMCs.

Imbalance handling and ancillary services

Imbalance management and ancillary services are indispensable for ensuring the reliability of the Indian power system. Power procurement planning is based on long-term contracts (around 90% of the market share) and in the day-ahead market most contracts are physical, not financial (and linked to a generator and supplier).

The intraday energy requirement – as well as system imbalances – were generally managed through the decentralised Deviation Settlement Mechanisms. CERC introduced the Ancillary Services Mechanisms in 2015, which obliged all regional generators (67 plants) to provide a centralised instrument to manage grid frequency and transmission congestion (CERC, 2018b). Ancillary services are used to provide essential system services, such as frequency control, voltage support and generation and transmission reserves. In India they are classified into: frequency control ancillary services (FCAS) (primary, secondary, tertiary), network control ancillary services (NCAS) for controlling voltage and power flow, and system restart ancillary services (SRAS), which are used to restore the system after a full or partial blackout. The NLDC (through the RLDCs) acts as the nodal agency for ancillary services and prepares the merit order stack.

As of today, there are generally four options for managing system imbalances in real time (CERC, 2018a):

- Deviation Settlement Mechanism or ancillary services
- intraday bilateral contingency transactions
- intraday market segment of the power exchanges
- rescheduling four time blocks ahead (right to recall).

Ancillary services are predominantly provided by thermal power plants. However, they have ramping limitations and cannot provide fast response (CERC, 2018b), which is needed in a power system that has to integrate rising shares of VRE. CERC proposed therefore to expand the scope of ancillary services to include hydropower generators under a new framework of fast response ancillary services for providing frequency regulation service.

CERC is also revisiting the rules and regulations concerning the Deviation Settlement Mechanism, ancillary services, the power markets and their nexus. It has observed that the mechanisms are often used over several hours to manage power system imbalances, thereby substituting energy trade within the intraday market (CERC, 2018a). CERC published a discussion paper related to redesigning provision of ancillary services, while also presenting proposals to improve the day-ahead market and the intraday market.

Furthermore, CERC has proposed the establishment of a clear gate closure time with binding schedules, which is an important step to improve the Indian power system in the future. A definition of minimal dispatchable unit is also needed to optimally mandate ancillary service-providing entities (CERC, 2018b). CERC's reform aims to ensure that there are no barriers to entry and exit – no technology should be stranded and the system operator should be able to access the most flexible technology at least possible cost (CERC, 2018b).

Power market design to support system integration of renewables

International experience suggests that in a system with rising shares of VRE, thermal power plants may offer increasingly important flexibility services to the power system, which are however, not always rewarded in the power market design. Depending on the time horizon, such services can be rewarded by several options: as dedicated strategic reserves, ancillary services and short-term grid reserves, or via dedicated capacity remuneration mechanisms alongside the wholesale energy market.

The independent electricity system operator in Ontario, Canada, is pursuing ongoing energy market reform to better match flexibility requirements with existing system resources through the introduction of a day-ahead market and enhanced real-time unit commitment, which will complement the real-time market. Similar discussions are ongoing in Australia's energy-only market. Other options include the introduction of scarcity pricing – such as in Electricity Reliability Council of Texas (ERCOT) – or capacity-based remuneration mechanisms.

The adjustment of market rules and codes is needed to determine the participation of flexibility resources in the power system. For jurisdictions with wholesale energy markets, regulators and market operators collaborate to implement changes to a variety of market rules, to ensure that all sources of flexibility can bid (such as storage, aggregators and the demand side) and act as both a wholesale buyer and seller of electricity. In the United States, for example, the Federal Energy Regulatory Commission (FERC) issued Order 841 in February 2018, which directs independent system operators and regional transmission organisations to open wholesale energy, ancillary services and capacity markets to energy storage resources (FERC, 2018). Once the rules are fully implemented by the deadline of December 2019, an enormous increase is expected in the participation of batteries in electricity markets across the United States.

As illustrated in Chapter 7 on electricity, India's power system has become more reliable following large-scale investment in capacity. The reduction in non-supplied energy is the result of the synchronisation and reduction in frequency deviation over the past decade. However, the use of this capacity remains inflexible, as the current market design does not ensure the efficient dispatch and use of the existing capacity. Of the total electricity procured in India in 2017/18, the short-term power market provided 11%. The balance was procured mainly by DISCOMs through long-term contracts and short-term intrastate transactions. But market participants are increasingly looking for short-term trades across India to optimise their portfolio. During 2009/10 to 2017/18 the volume of short-term electricity transactions increased at a higher yearly rate (9%) than gross electricity generation (6%). In the past decade, the volume traded at power exchanges has increased steadily, but is still very low (see Chapter 7 on electricity).

Experience around the world shows that a shift to more liquid and short-term markets with shorter gate closure periods helps foster the optimal dispatch and trading of renewable electricity and allow efficient use of all power system resources.

India is moving in this direction – an intraday market was specifically introduced at the power exchange to address the need to meet energy requirements closer to real time. However, the overall volume of trades is still very low at the exchanges compared to the volume of contracts in the market. The need for an efficient short-term market design remains critical for an optimised dispatch of power plants, notably renewables, across the country. Solving this will allow a smooth integration of the 2022 target 175 GW of renewable energy.

In India stakeholders at the central level are aware of the critical importance of wholesale market reform to improve the financial viability of the system and achieve the successful system integration of rising VRE shares. One of the greatest barriers to such reform are the existing PPAs between DISCOMs and thermal generators. These contracts lead to a physical delivery obligation of specific plants to specific DISCOMs who self-schedule these generators (meaning they are not dispatched in the most economic or transparent way). This makes it challenging for generators to bid into the wholesale market, even if they technically have idle capacity.

CERC is consulting on changes to the market design, which include provisions for unlocking flexibility by separating the contractual financial obligations of existing PPAs from the physical dispatch (CERC, 2018a). PPAs could be converted into a contract-for-difference with a strike price against the short-term market price. As described above, CERC has also tabled proposals for introducing real-time markets and ancillary services markets (CERC, 2018b; 2018c).

Flexibility resources in India

Within the IEA system integration approach, four categories of electricity infrastructure assets are considered critical for system flexibility: a) power plants (both conventional and variable renewable resources); b) electricity networks; c) distributed energy resources; and d) energy storage.

Conventional power plants, electricity networks and pumped storage hydropower have historically been the primary sources of flexibility. However, thanks to operational protocol improvements in VRE power plants, smarter electricity networks and more affordable distributed energy resources and battery electricity storage, a wider set of flexibility options is available. As power systems transition towards higher phases of system integration, these flexibility resources can work together in concert to enhance system flexibility in a cost-effective, reliable and sustainable manner. Achieving this goal typically requires changes to policy, market and regulatory frameworks.

The following section examines these flexibility sources and their availability in India.

Power plants

Thermal plants

In India's power system, conventional power plants are the predominant source of system flexibility to accommodate supply and demand variability and uncertainty. Conventional power plants can be operated more flexibly by rapidly changing plant output, by starting and stopping more quickly, and by turning plant output down to lower levels. There is a diverse range of strategies that can make existing conventional power plants more flexible.

CERC has taken measures to enhance the flexibility of the thermal generation fleet, although progress has been limited to the central level power plants (around 54 GW of capacity) or one-quarter of the thermal fleet in India. In 2017 the CERC passed regulations that require the minimum generation level from the central plants to be reduced from 70% to 55%. This lower limit was already covered under the Indian grid code, which allowed for the swift implementation of the measure. This was a commendable and pragmatic step to mobilise system flexibility.

However, central plants – most of them owned and operated by the National Thermal Power Corporation of India (NTPC) – are already among the most efficient in the country. It would be more economical to reduce the output of less-efficient state-level generation. Ensuring more flexible operations in the remaining fleet, notably the state-owned plants and independent power producers, requires separate regulations to be adopted by each state regulatory commission.

In 2018 a committee was set up under the Central Electricity Authority and the Chairmanship of Chief Engineer to identify the amount of flexible thermal power and ramp rates required from thermal power plants, propose a methodology for the identification of these units that should run "flexibly" and develop a road map for implementation of these measures across India. In its report, the committee found that coal-fired power plants should provide the bulk of the flexibility, but hydro and gas should also be expected to play a pivotal role, alongside demand-side management (CEA, 2019b). Ramp rate was not found to be a challenge for system integration of renewable generation. Individual power plants, however, need to be capable of ramp rates of at least 1%/minute.

The committee underlined that a financial framework for flexible operation of thermal power was needed and suggested a road map for economical and flexible operation of various sizes of thermal unit (based on preliminary estimates for the capital investment and increase in operational expenditure for thermal generation). The committee also emphasised the urgent need for regulatory intervention in the form of revision of grid codes and tariff structures for supplying flexible power into the grid from conventional sources of generation and storage.

In May 2019 a CEA committee was set up to identify, in consultation with central/state utilities, the thermal units for pilot testing of flexible operation. The identified units will run pilot tests of low load operations (40-45%) as well as ramp-up/ ramp-down capabilities, with a gap analysis and modifications, where required.

These are steps in the right direction to unlock the flexibility of thermal power plants. The National Renewable Energy Laboratory (NREL) "Greening the Grid" study demonstrated that further lowering coal plant minimum generation levels from 55% (current mandate for centrally operated plants) to 40% would nearly halve system-wide VRE curtailment, which also improves the bankability of VRE projects (NREL, 2017). Further, if such a minimum generation policy was pursued in combination with expanded co-ordination among balancing areas, additional savings could be achieved.

However, besides the technical constraints, certain operational procedures also limit access to physical flexibility in the system. First, closer to the time, states have limited options to update interstate transmission schedules in response to load and VRE forecasts. Revising schedules and dispatch closer to real time would increase the ability of other plants to react to changes in the system. Second, there is currently no efficient mechanism for accessing operating reserves at the state or regional level (as they are not included in the ancillary services regulated by CERC). Optimising reserves would allow for increased access to faster ramping or lower turndown units. Various interstate reserve markets have been proposed by CERC.

POSOCO also has plans to develop an automatic generation control (AGC) pilot project at a regionally dispatched generation plant. This may pave the way for more cost-effective use of generation reserves, and it will provide a new revenue stream for these individual power plants. The Central Electricity Authority (CEA) of India is considering implementing AGC at all coal-fired power plants, and has recently begun an AGC pilot project at the NTPC Dadri Stage-II power plant. AGC technology is widely implemented in European and North American power systems.

VRE sources

VRE is often perceived as the key driver of new flexibility requirements. VRE power plants can also provide flexibility services themselves to address a range of operational issues related to power systems; however, this requires adequate technical requirements, and in some cases economic incentives, to operate at their full range of technical capability.

First, appropriate connection codes need to require VRE to provide flexibility services, which will increase the visibility and controllability of VRE resources to system operators (IEA, 2017). Second, VRE generators may need to be remunerated for providing specific flexibility services, just as conventional power plants are.

Modern VRE resources can be operated flexibly by either running at full output and dispatching downward ("downward dispatch mode") or running at a reduced output and using this "headroom" to be dispatched upward or downward when needed ("full flexibility mode"). The impact of these operating modes has been studied in the Tampa Electric Company system in Florida (Energy and Environmental Economics, 2018, IEA, 2019d). As solar PV penetration increases on the grid, this example shows that flexible operation of these resources provides operational cost savings, notably when the plants are operated in "full flexibility" mode.

Turning to the remuneration of VRE power plants, the transition to auctions in India raises system integration concerns. As shown in Chapter 5 on renewable energy, the reverse-auction system for building new capacity has very low price caps, designed with the levelised costs of electricity at sites with very high wind speeds. However, sites are very different across India and these caps may not be achieved at all sites. The price caps put a pressure on developers to cut costs. This creates the risk of installing low-quality VRE capacity, which may have shorter life spans, not perform according to technical specifications, and be unable to operate in flexible operating modes.

This issue is compounded by the lack of provision in and complex governance of Indian grid codes, which are a shared responsibility between the central and state levels. Currently VRE plants are not required to have state-of-the-art ability to provide system services. With the rapid growth in solar PV in India, the flexibility capabilities from PV plants are critical. Particular attention should be paid to system stability at high shares of non-synchronous generation and the necessary technical specifications for VRE plants. Development of an integrated code could be led by CERC through the Forum of Regulators, and supported by the CEA and POSOCO, in close co-operation with SLDCs and renewable plant developers and owners.

Electricity networks and grid infrastructure

International experience shows that electricity networks and interconnections (intra- and inter-regional) bring multiple benefits to the power system, notably improved security of supply, improved efficiency and better integration of variable renewable resources (IEA, 2014; IEA, 2016). Electricity networks enable system flexibility by allowing a broader set of flexible resources to be shared across different geographical regions. Interconnection capacity allows for an increase in demand to be met by a generator in a neighbouring region when local generation resources are already at maximum output. Moreover, electricity networks allow other flexibility options to be shared across a wider area, such as a large energy storage facility. As such, interconnections play a very important role in providing flexibility as power systems transition toward higher VRE integration phases. VRE resources typically have a smoother aggregate profile that is easier to integrate across a larger region. Today, significant flexibility resources are still being underutilised due to transmission and interconnection bottlenecks, a situation likely to worsen with high renewables deployment of 450 GW.

The risk of renewables investment outpacing transmission and interconnection capacity is high. In the international context a typical interconnector infrastructure project (transmission connecting countries/regions) takes about ten years to develop and build, and calls for significant amounts of research and numerous studies before permits are granted by regulators and final investment decisions are made by investors. By contrast, the development of renewables can take less than one year. This issue has been fully acknowledged by the GoI.

Over past decades India has successfully built out its interstate transmission system and since 31 December 2013 the country has operated a single synchronously operated grid. The government put in place a concerted action programme to plan and build interstate transmission lines and connect renewable energy resources. The Green Energy Corridors plan shows that transmission lines can be built relatively swiftly in two to three years following the competitive bidding process; however, projects can sometimes, notably at the state level, can take longer than five years due to rights of way issues in densely populated areas. Another positive experience is that renewable generation does not pay transmission charges (for a limited period in time), when they connect to these interstate transmission lines, which fosters “grid-friendly” deployment.

Interconnectivity across regions has increased sharply in India – it has added an average of 21 000 circuit kilometres of transmission lines (220 kV and above) every year since 2012. The total amount of capacity added over the past seven years is equivalent to the entire high-voltage grid of Germany. Despite major investment in large-scale interstate grid integration, important state transmission lines across India remain congested and constrained. Total interregional transmission capacity amounted to 75 GW on 31 March 2017. However, the available transmission capacity on a daily basis does not exceed 35% of total transmission capacity and actual usage is around 25%, according to POSOCO. Besides, much of the renewable energy deployment is taking place at the lower-voltage level of transmission and distribution. At state level there are multiple barriers to financing transmission investment, including land acquisition, permitting and lack of financing. The risk of solar, wind and other flexible resources being locked behind transmission bottlenecks is higher for state infrastructure-connected projects. Further infrastructure buildout will be critical to balancing a higher level of supply-side variability at a time of rising shares of VRE. Given the long timeframe for project development, it is important for policy makers to proactively lead public engagement and promote a sense of confidence that projects are in the public interest of all citizens.

Case study – Green Energy Corridors

The Ministry of Power (MoP) has directed CERC to provide early regulatory approval for a transmission investment of "national importance" (necessary to integrate and meet the renewables target for 2022).

In 2015/16 the MoP sanctioned investment in both the intra- and interstate transmission systems under the Green Energy Corridor scheme to remove system integration barriers for large-scale renewable energy projects. The project is being implemented by the respective state transmission utilities in the eight VRE-rich states of Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh and Madhya Pradesh. The scheme incentivises wind and solar developers to connect directly to these Green Energy Corridors by promising zero transmission charges until 2022 for the projects connected to these lines.

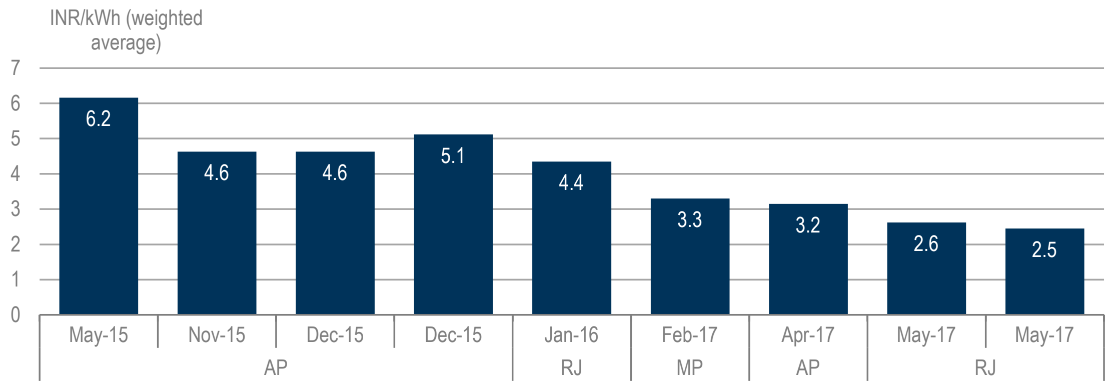
To date, two phases have been implemented: Phase I included investment in intrastate and interstate transmission and REMCs to integrate a total of 33 GW of renewable energy. Phase II aims to connect 100 GW of solar and 60 GW of wind generation capacity by 2022. In total, by 2020, 9 400 circuit kilometres of transmission lines and substations (19 000 MVA) are planned.

The state transmission utilities introduced a competitive bidding process to implement the corridors. Such intrastate transmission investments have been funded by 20% equity from the central government, 40% grant from National Clean Energy and Environment Fund (NCEF) and 40% soft loan, whereas, the interstate transmission schemes are funded by 30% equity from Powergrid and 70% soft loans. Loans have been provided by the German Kreditanstalt fuer Wiederaufbau and the Asian Development Bank.

Mitigating electricity network connection risk has been identified as a priority to manage the cost and integration of VRE generation. India's Ministry of New and Renewable Energy (MNRE) introduced a solar park policy under the overall target of 100 GW of additional solar generation by 2022. Transmission lines are needed to connect these solar parks, which should be strategically located to ease VRE integration challenges and reduce system flexibility needs. The policy has successfully attracted investors by removing obstacles to transmission connection, including risks related to permitting and rights of way.

The weighted average tariffs awarded for projects within the different solar parks have declined between 2015 and 2017 under the policy (Figure 8.9). The policy also encourages hybrid projects incorporating wind or storage with PV systems to provide improved flexibility and reduce variability. As of August 2017, 36 solar parks in 21 Indian states with an aggregate capacity of around 21 GW had been approved and were at various stages of development.

Figure 8.9 Average tariffs awarded to projects in different solar parks under the solar park policy



Solar parks have been an effective approach to mitigating grid connection risk and reducing system flexibility requirements in India, while driving down VRE procurement costs.

Note: Each tariff refers to a different solar park within the following states: Andhra Pradesh (AP), Rajasthan (RJ) and Madhya Pradesh (MP).

Source: MNRE (2017), *Success Story of Solar Parks in India*, https://mnre.gov.in/file-manager/akshay-urja/october-2017/Images/37-41.pdf.

Distributed resources

Distributed energy resources are poised to grow significantly in India in the coming decades. These resources include distributed generation, distributed battery storage, demand response and EVs. While they have a number of benefits for individual customers, from the power system perspective they also have the potential to provide system flexibility services at the local level and also at the bulk power system level if aggregated.

Solar capacity targets include 60 GW of utility-scale investment at 36 solar power parks in 21 states and 40 GW of rooftop solar. In the light of these ambitious distributed PV targets, the growth of non-registered rooftop PV systems could become a near-term system integration challenge for India. These systems often do not comply with system security and grid code specifications and if growth reaches sizeable shares, such installations can challenge system stability in distribution systems. Visibility of these assets for system operators is another challenge. One option to incentivise registration, compliance and visibility of plants is to provide appropriate remuneration for injections into the grid or other incentives to promote registration. The cost of such schemes should be weighed against the expected benefits from reliable grid operation. Forecasting of distributed solar may also pose challenges in the future.

A new scheme to support farmers to replace existing diesel pumps with solar PV pumps has been initiated by the GoI in early 2019. One million of these pumps are planned to be grid connected, and thus system integration considerations will be important. The policy will allow farmers to become prosumers and sell power to the DISCOMs at a predetermined feed-in-tariff. This may not, however, allow DISCOMS to use these pumps for system flexibility. The scheme aims to add solar and other renewable capacity of 25.75 GW by 2022. The feed-in-tariff type of remuneration of such a large number of solar PV installations can pose a system operation challenge if the feed-in will be automatic without DISCOMs having curtailment options.

Demand response and retail pricing

The retail price is the most important price signal provided to distributed energy resources, most directly under net metering, which defines the value of distributed energy resources that feed electricity directly into the grid or indirectly as the value perception of end users. The net metering schemes introduced in 28 Indian states support the expansion of distributed solar PV. However, net metering does not tackle the question of optimal system integration of these resources.

Retail prices can also provide signals for demand-side management and demand-side flexibility services, such as demand response through time-of-use or time-of-day pricing to industrial, agricultural and commercial consumers. Demand-side management is defined as an often-involuntary traditional arrangement, such as interrupting service at critical times or ripple control by distribution companies (for example, the timing and scheduling of night power for electric boilers in France). Demand response, in contrast, means a typically voluntary response to a price signal.

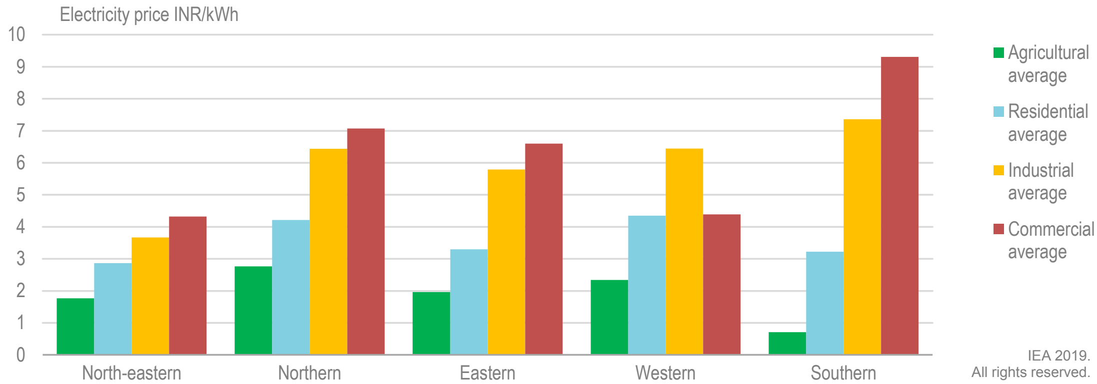
Demand response, generally speaking, is driven by the end-use customer's desire to reduce electricity costs (or associated price and volume risks). This goal can be accomplished either through retail electricity cost savings via an appropriate retail electricity contract or tariff, or through wholesale market revenue via payments as a participating supply-side resource. On the demand side, the customer may reduce electricity consumption when the retail price is high and increase consumption when the retail price is low to reduce overall electricity cost. On the supply side, the customer may receive a payment to reduce load when the wholesale price is high (potentially resulting in an increase in consumption when the price is lower) and use the payment (or "revenue") from the wholesale market to reduce electricity cost. Both approaches enable customers that are price sensitive to reduce electricity cost.

India has significant historic experience with demand-side management. India's DISCOMs have traditionally suffered from the lack of available generation capacity, and they have therefore frequently used demand shedding as a local system balancing tool. This made electricity demand in India *de facto* highly responsive to price or supply changes, a remarkable difference to most countries in the world.

Time-of-day (TOD) tariffs are already used in India's industrial sector; they are mandatory in certain states for energy-intensive consumers and are being introduced in the commercial sector. By setting different prices for energy consumed at different hours, TOD encourages energy-intensive consumers to introduce demand response. For instance, industrial consumers are very sensitive to electricity price changes and a large amount of steel, chemicals and cement manufacturing capacity is able to shed load. The profile of the TOD tariff differs by state, based on the state generation mix and load profile. Peak hours are usually between 18.00 and 22.00. In some states, months or monsoon seasons can be relevant for price setting, too (CEA, 2014). Even at lower electricity prices, large amounts of load can be easily shed for 5 to 8 hours, for instance for refrigeration, cooling, cleaning and water heating. This situation is quite specific to India.

To leverage this demand flexibility for better system integration of renewables, further changes to the retail pricing and tariff systems are needed. Electricity retail tariffs are approved by State Electricity Regulatory Commissions (SERCs) for each DISCOM with respect to their respective monopolistic regions. Therefore, the price of electricity mirrors the generation mix costs for the specific region within the state. India's retail tariffs show great variance between different states and across different end-user types. Average commercial and industrial prices are very high compared to average agricultural and residential prices, mainly due to highly subsidised retail tariffs in the agricultural sector (Figure 8.10).

Figure 8.10 End-user electricity prices for different regions, 2015



Note: avg. = average.

Source: Power Finance Corporation (2016), *The Performance of State Power Utilities for the Years 2013-14 to 2015-16*, www.pfcindia.com/DocumentRepository/ckfinder/files/Operations/Performance_Reports_of_State_Power_Utilities/1_ReportonhePerformanceofStatePowerUtilities2013-14to2015-16.pdf.

International experience suggests that subsidised final electricity prices can reduce the incentive for the deployment of demand management, demand response and energy efficiency programmes.

The high level of cross subsidies levied on industrial consumers to subsidise lower prices for other consumers are a barrier to further pricing reforms. In fact, high industrial electricity prices incentivise industrial users to self-generate electricity for self-consumption, for example using solar PV instead. This trend has been very strong in India, leaving higher proportions of network charges to be paid by the users of remaining units. At the same time, industrial demand response is then no longer available to support grid management and flexibility.

EVs

Electric car sales in India are still negligible as a share of vehicle sales. In 2013 the GoI launched the National Electric Mobility Mission Plan 2020. The government has a target for 15% of vehicle sales to be electric by 2022 and introduced a significant incentive programme, the so-called Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles, or FAME. It provides subsidies to cities across India worth around 60% of the cost of the purchase of EVs. India also has a support programme for local EV manufacturers. Many states, such as Karnataka, Telangana, Delhi, Andhra Pradesh and Maharastra, have followed national policy and set state-level targets for the deployment of EVs, including electric buses.

Depending on the charging method used, EVs can provide flexibility resources to the power system (smart charging, time-of-use charging, vehicle-to-grid [V2G] services). However, they can also create significant system integration challenges locally.

In line with the EV ramp-up, further adjustments to the TOD tariff systems will be required. As of today 13 Indian states have a defined tariff for charging of EVs, but only 4 states (Delhi, Maharashtra, Uttar Pradesh and Telangana) have applied TOD pricing to the category. Previous studies on the impact of EV charging on system integration have found that fixed time-of-use pricing approaches can have negative side effects for the system, because EV charging can contribute to capacity spikes that can occur at the beginning of low-cost time windows. Hence, promoting managed charging of entire EV fleets in line with real-time system conditions is likely to be the preferable option once EVs achieve scale.

Storage

With the increased share of variable renewables, the flexibility provided by storage resources will become increasingly important. In India and globally, PSH remains the most widely deployed utility-scale storage option. By absorbing off-peak energy and providing peak power, PSH also improves the overall economy of power system operation and increases the capacity utilisation of thermal stations. PSH resources, are however, highly geography specific and are not available everywhere. To support system flexibility, PSH can play an important role in several states as long as existing regulatory and tariff barriers can be overcome.

India has significant hydro reservoir capacity and a large PSH potential, which, however, remains untapped (MNRE, 2015). Out of more than 90 GW of PSH potential in the country, only 4.8 GW is designed and capable of operating as pumped storage units. The 4.8 GW of capacity is provided by nine PSH plants. Only 6 power plants (24 units) with a capacity of 3.3 GW are operational today. Table 8.3 shows the allocation of PSH capacity in six Indian states.

Table 8.3 PSH capacity (≥ 25 MW), 2019

No.	Station	Capacity (MW)	State	Region	Present operational status for pumping mode
1	**Ghatghar**	2x125	Maharashtra	Western	Operational
2	**Nagarjuna Sagar**	7x100.8	Telangana	Southern	Operational
3	**Kadamparai**	4x100	Tamil Nadu	Southern	Operational
4	**Bhira**	1x150	Maharashtra	Western	Operational
5	**Srisailam**	6x150	Telangana	Southern	Operational
6	**Purlia**	4x225	West Bengal	Eastern	Operational
7	**Kadana**	4x60	Gujarat	Western	Not operational
8	**Panchet Hill**	1x40	DVC	Eastern	Not operational
9	**Sardar Sarovar**	6x200	Gujarat	Western	Not operational

Source: CEA (2019c), *Pumped Storage Development in India (Installed Capacity above 25MW)*, www.cea.nic.in/reports/monthly/hydro/2019/pump_storage-01.pdf.

Battery storage

The rapid decline in global battery technology costs is creating an opportunity for battery energy storage systems to play a larger role in providing power system flexibility. They offer fast and accurate responses to dispatch signals from system operators, and their modularity enables a wide range of installation sizes and potential locations for deployment. However, they are not yet a fully cost-competitive flexibility resource. While further cost reductions and improvements in the technology performance are expected, market and regulatory designs need to ensure battery storage can participate within the power markets and offer the full range of services.

To date in India, battery projects have been small and limited. Deployment of utility-scale batteries started in 2017 with a Powergrid project. One of the largest battery projects includes the 10 MW battery installed by AEAS Mitsubishi. Additionally nine utility-scale battery storage projects are expected to be commissioned in 2019. According to the draft study by the CEA into the optimal generation mix for 2030, India would need 34 GW of grid-connected battery storage producing 136 gigawatt hours (GWh) by 2030 (CEA, 2019d).

The India Smart Grid Forum and India Energy Storage Alliance draft Energy Storage System Roadmap for India (2019-32) expects the market for grid-connected battery storage to be around 62 GWh by 2027 (ISGF, 2019).

India's National Mission on Transformative Mobility and Battery Storage, established in 2019, sets out a five-year manufacturing programme (up to 2024) for India to become a competitive, export-oriented and large battery manufacturer along the entire value chain by setting up integrated battery- and cell-manufacturing giga-factories (NITI Aayog and RMI, 2019; 2017).

Several international players are providing further support for the deployment of storage technologies in India, including the Accelerating Battery Storage for Development programme of the World Bank's Energy Sector Management Assistance Programme (ESMAP).

According to the NREL "Greening the Grid" study, batteries could significantly impact emissions and the total cost of system integration. They could reduce curtailment by 0.3% (from 1.4% to 1.1%) by 2022. However, this value could be offset by losses in operational efficiency. So, for example, 2.5 GW batteries (75% efficient) would reduce renewables curtailment by 1.2 TWh annually, but efficiency losses could amount to 2.0 TWh (NREL, 2017).

The main contribution of batteries to power system flexibility is frequency regulation services and services in support of short-term local transmission congestion events (peak shaving, network investment deferral). In-depth state-level power system analysis is needed to identify the role of storage and battery storage in each state.

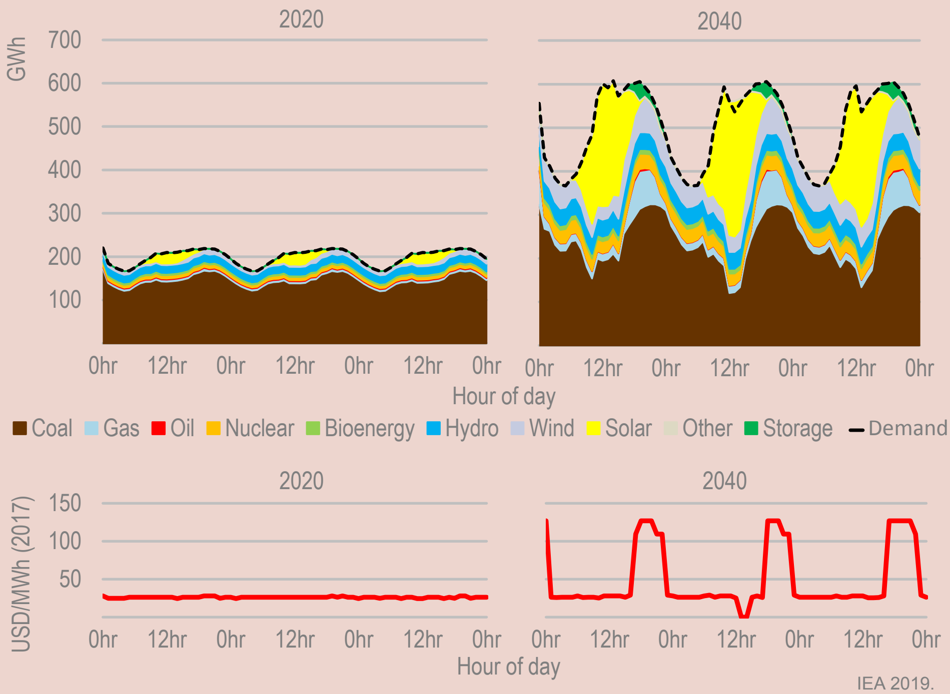
Future sector coupling, hydrogen (ammonia)

Conversion of solar electricity to secondary energy carriers (hydrogen and its derivatives, such as ammonia) may be a relevant option to achieve continued system integration. Gas infrastructure planning could today consider the possibility of transporting hydrogen at a future stage and, where cost-effective, ensure advance compatibility with later use for hydrogen. The direct application of hydrogen in industry processes (fertiliser production, direct reduction of iron and steel making) is an option that could be commercially viable in the short to medium term and provides an opportunity to gain experience and develop technologies for sector coupling.

Box 8.1 Power system flexibility in India in 2040

According to IEA *World Energy Outlook* analysis supported by the IEA's System Integration model of India, adequate system flexibility is essential for the security and reliability of electricity supply in India in the coming decades of 2020 to 2040. Flexibility needs are expected to increase dramatically as the profile of demand becomes more variable, with higher peaks, and as the share of solar PV and wind increases from 4% in 2017 to 28% in 2040. (Figure 8.11) Given the seasonality of India's wind generation and the steep drop in generation from solar at sundown in all the modelled regions, storage is deemed to play an important role in the electricity markets. By 2040 India accounts for 60 GW out of almost 220 GW of global battery storage capacity. Hydropower also contributes to the flexibility in India's power systems, reaching nearly 110 GW of installed capacity by 2040 in the IEA modelling analysis.

Figure 8.11 Hourly generation mix and wholesale market price of electricity in India in the New Policies Scenario, 2020 and 2040



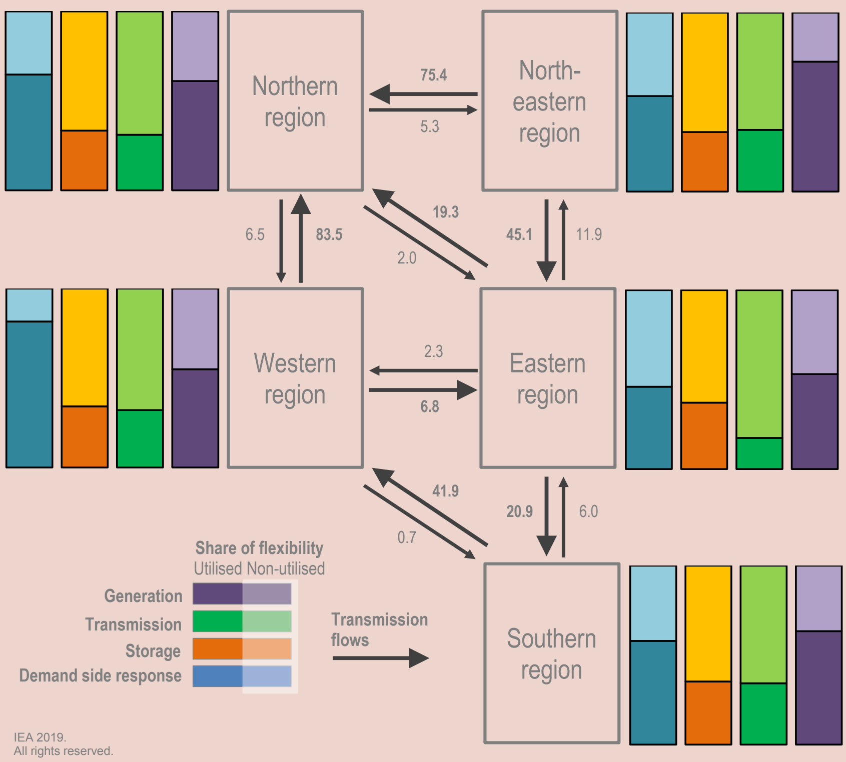
Source: Adapted from IEA (2018a), *World Energy Outlook 2018*.

Higher VRE penetration leads to increased flexibility needs, which were assessed with an expanded suite of modelling tools. A combination of four flexible resources – power plant flexibility, better interconnections between the five sub-regions, demand-side response and energy storage – helps meet this requirement. The contribution that each of these resources makes varies across regions, reflecting different levels of availability (Figure 8.12). For example, in terms of generation, the north-eastern region uses a high proportion of the flexibility available from hydropower, due to its relatively low operating costs.

Given their dominant role in electricity supply, coal-fired power plants are a critical part of the flexibility picture in India, and efforts are underway to enhance their ability to respond to system needs. Use of transmission capacity is similar for each region, with the eastern part of India having the lowest rate of utilisation of transmission capacity, driven in large part by its connectivity with all the other regions. The average use of demand-side response resources is higher in the western, northern and southern regions, driven by the strong presence of wind and solar.

Electricity demand for space cooling accounts for a major share of demand-side response potential in all regions; however, barriers exist to tapping this potential, especially in residential buildings. As a result, sources of demand-side response utilised in the modelling are more diverse, with contributions from water heating (mostly in the north), water pumping in agriculture, EV charging, commercial refrigeration and certain industrial processes. However, in all of the modelled regions demand-side response is used at or close to its full potential during times of system stress. Storage shows a more homogeneous use pattern across regions, with the usage level consistent with operation at approximately one daily charge and discharge cycle. Indeed, on most days of the year, available storage is charged and discharged to its maximum.

Figure 8.12 Regional utilisation of flexibility options in India in the New Policies Scenario, TWh



Source: Adapted from IEA (2018a), *World Energy Outlook 2018*.

In the absence of storage or demand-side response, wind and solar output exceeds power demand by up to almost 60 GW in some hours. Demand-side response reduces this to less than 6 GW, and storage eliminates all these periods. VRE curtailment due to some generation constraints (such as must-run generation) is about 5 TWh over the course of the year in 2040, meaning that more than 99% of all available wind and solar generation is utilised (assuming economic dispatch in year 2040). These flexibility options help to remove barriers that might otherwise limit further deployment of renewables in India. Regulation needs to support an adequate level of capacity to provide supply security, flexibility and stabilisation services to the grid, while avoiding excessive costs to the consumer or to the government, by way of subsidies.

IEA flexibility analysis – A scenario outlook to 2040

This section provides a quantitative analysis developed by the IEA of the four flexibility resources (generation, transmission, storage, demand-side response) available to the Indian power system in the future. The section reflects the *World Energy Outlook 2018* New Policies Scenario (the IEA scenario that assumes that existing and agreed policies will be implemented, but to-be-announced new policies are not included).

Recent analysis has identified battery storage as the main and often only new source of power system flexibility. There is little analysis of India's power system that has considered flexibility from demand response and price signals, regional integration or even VRE, even though all of these can be cost-effective flexibility options under certain policy and technology conditions. Besides, the local value of these flexibility options is not taken into account in these analyses. To bridge the gap the IEA is working with the State of Gujarat on a state-level analysis to quantify the contributions from the different flexibility options in the power system.

Assessment

System integration of variable renewables is a topic of growing importance, which concerns the flexibility of both the existing power system and new resources of flexibility. While at low shares of VRE power system security concerns are typically low, at higher shares, such as witnessed in the renewables-rich states in India, system inflexibility can become a barrier for further VRE expansion.

As of 2018 India is in Phase 2 of the IEA System Integration of Renewables phase assessment. However, a more in-depth review of the Indian power system at state level shows a very diverse picture. Six states are already facing significant system integration challenges at Phase 3 and several states have entered Phase 2, while the majority of Indian states still belong in Phase 1. In the future, the IEA expects several Indian states to enter Phase 4 and Phase 3 of system integration, which will bring about significant changes to how their power systems are operated.

The central government and several state governments are well aware of the challenge and have made significant efforts to promote system integration. However, not all states are in the same phase and some face more challenges than others. A significant opportunity exists to improve the flexibility of their power systems with the exponential increase of renewables, as India moves towards the implementation of its 175 GW target of renewables by 2022. National and state-level co-ordination and public and private sector co-ordination will require the collaboration of a broad range of players: over 600 generators, more than 30 transmission licensees, more than 70 distribution utilities, more than 30 system operators (load dispatch centres), 2 power exchanges and 43 traders.

Looking ahead, promoting the adoption of ongoing national reforms at the state level will be crucial. This is likely to require a concerted effort to build a shared understanding of the nature and benefits of the proposed mechanisms. Reform will only be able to move forward if states have confidence that it will actually maintain or even increase their DISCOMs' access to reliable and affordable power.

The critical system integration challenges and opportunities can be grouped into the following three categories: system operation; market design; and developing all sources of flexibility.

The central government and regulators are already addressing many of these areas, but further effort is needed to ensure implementation at state level and co-ordination across regions.

Advanced system operation

Advanced system operation practices, such as better scheduling and forecasting of VRE, will help grid operators to commit or de-commit generators to accommodate changes in wind and solar generation more efficiently and prepare for extreme events when renewable generation is unusually high or low.

The ongoing introduction of Renewable Energy Management Centres (REMCs) is a critical step towards advanced system operation practices. REMCs activities include enhancing the operational flexibility of power plants, making efficient use of the transmission grid and ensuring that VRE power plants have the capability to provide system services. This includes the adoption of state-of-the-art automated load and renewable energy forecasting systems.

India has started improving the co-ordination of scheduling and dispatch between neighbouring states, which will allow better access to least-cost generation and flexibility (a first step towards regional economic dispatch). Additional system flexibility can be provided by expanding the balancing areas to have imbalance netting over larger areas and reduce costs by tapping into a larger pool of balancing resources/demand. The REMCs are an excellent tool, but their success also depends on the capacity of the dispatch centres at the state level (who do not yet schedule or dispatch in an economically efficient way) and the ability of transmission utilities to fast-track transmission investment and remove congestion. Improving system development and planning capabilities at the state level should be considered a top priority.

The responsibility for grid codes is shared between the central and state levels of government, an arrangement that needs to be harmonised to ensure that VRE plants have incentives to provide state-of-the-art system services. However, with increasing deployment of VRE, the requirement for renewables generators to provide grid services such as AGC and operational data will become very important in the coming years.

Upgraded connection requirements and codes need to cover all technologies (VRE, conventional generation, storage, and distributed and demand-side resources) so that transmission licensees and system operators have greater flexibility resources at their disposal.

Improving electricity market design

The design of wholesale power markets plays a critical role in ensuring reliable system operation along the three time frames of resource adequacy, flexibility and stability.

The 2018 CERC proposals for wholesale market reform represents a step towards a more flexible power system. To achieve reliable market price signals in India, a higher level of liquidity of power markets will be essential. Furthermore, shorter settlement times and trading closer to gate closure time (plus the introduction of gate closure), can enable better management of variable generation.

Market operations also have a critical impact on making technical flexibility potential available in practice. Market price signals can be the key incentive to accessing the full flexibility capabilities of existing coal, gas turbine, hydro and PSH generation. Such signals could be provided through: a) the development of a new tariff structure that specifies a performance criterion (ramping), and that addresses the value of coal, gas and hydro; and b) the development of model power purchase agreements for renewable energy that move away from must-run status.

The ongoing retail market reform and separation of the DISCOMs' retail and distribution activities are targets to ensure retail competition. This competition, if implemented, can bring forward further demand-side innovation and increased demand-side flexibility, especially if coupled with time-of-use price signals. As explained in Chapter 7 on electricity, retail market reform should focus on rationalising pricing structures and methodologies across India and phase out cross-subsidies or indirect subsidies.

Flexibility resources

New CERC regulations have already provided greater coal plant flexibility by reducing minimum operating levels for coal plants, increasing the availability of storage devices through the broadening of ancillary services and reserves, and promoting flexibility from wind and solar plants as well as PSH. CERC guidelines for state-level regulators should provide for the wider application of these regulations, which only are relevant for central plants to date.

Network development and planning co-ordination at state level and enhanced analytical and planning capabilities are indispensable for understanding possible medium- to long-term challenges and developing options in a timely manner. An excellent example of regional co-ordination is the Green Energy Corridors scheme that enables transmission of renewables from regions with high concentrations of renewable energy sources towards high-demand centres. Financing of Phase 3 of the scheme needs to be swiftly approved to ensure sufficient progress for system integration.

In states approaching Phases 3 and Phase 4 of system integration, unlocking the contribution of advanced flexibility measures – such as demand-side response and storage – becomes crucial, as with the rising deployment of decentralised rooftop solar

PVs and EVs more focus will be required on addressing integration issues at the distribution grid level.

Two factors can accelerate the adoption of demand-side response in India. First, the relatively low reliability of the Indian power system has led to widespread installation of diesel-fired back-up power. But the high cost of diesel and the falling costs of distributed generation favour the deployment of batteries, coupled with solar PV systems. Contrary to many other countries, electricity consumers in India are highly price sensitive and are used to actively managing their electricity use as a result of poor reliability. Second, the rapid decline in technology costs of battery energy storage systems is creating an opportunity for them to play a larger role in providing power system flexibility. This includes grid-scale battery storage and battery storage from EVs. These could bring system benefits, if appropriate tariff and regulatory measures are in place.

To consistently activate these flexible resources in normal operations (without blackouts), introduction of time-of-use pricing is recommended. This will support both system flexibility and overall cost reductions. As a first step, commercial and smaller industrial customers could be targeted. If prices were able to float freely during the day, they would be quite low during the daytime (boosting demand at times of high solar PV generation) and surge during periods of system stress in the evening hours, thus prompting the use of customer-side flexibility including electric batteries.

In addition, EVs can make an important contribution to load shifting by moving charging periods towards the middle of the day. However, this requires an appropriate strategy for developing charging infrastructure so that daytime charging is available. Previous studies on the impact of EV charging on system integration have found that rigid time-of-use pricing approaches can have negative side-effects on the system. EVs can contribute to demand spikes if a mass of owners begin charging at the start of low-cost time windows. Hence, promoting managed charging of entire EV fleets in line with real-time system conditions is a preferable option as EVs reach scale.

Recommendations

The Government of India should:

- Support capacity building for SLDCs to adopt advanced operation protocols, including renewable energy forecasting and automatic generation control.
- Encourage the development of a forward-looking, countrywide, enforceable grid code for all generators including VRE (both large scale and distributed) that includes the capabilities required to operate at very high shares of converter-based generation.
- Work closely with state regulators to promote pilots of time-of-use electricity pricing to incentivise demand-side response in the commercial and industrial sectors as well as for producers (prosumers) of electricity.
- Develop planning capacities at central level, as well as state and DISCOM level, with specific emphasis on:

- assessing the contribution of a wider range of flexibility resources to the power system as part of planning
- adjusting DISCOM planning frameworks to better include distributed energy resources (VRE and other generation, storage and demand response)
- promoting integrated power system planning, including advanced flexibility options such as demand-side response and energy storage
- implementing cross-sectoral planning at central and state level, including interactions between transport (EVs) and possibilities for the use of hydrogen and its derivatives to provide flexibility.

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9. Coal

Key IEA data

(2017*)

Coal production: 726 Mt, up 48% since 2007

Coal imports: 209 Mt imported (125 Mt hard coal, 84 Mt brown coal), up 320% since 2007

Share of coal: 44% of TPES and 74% of electricity generation

Consumption by sector: 937 Mt (power and heat generation 73.7%, industry 17.6%, other energy industry** 5.8%, residential and service 3.3%)

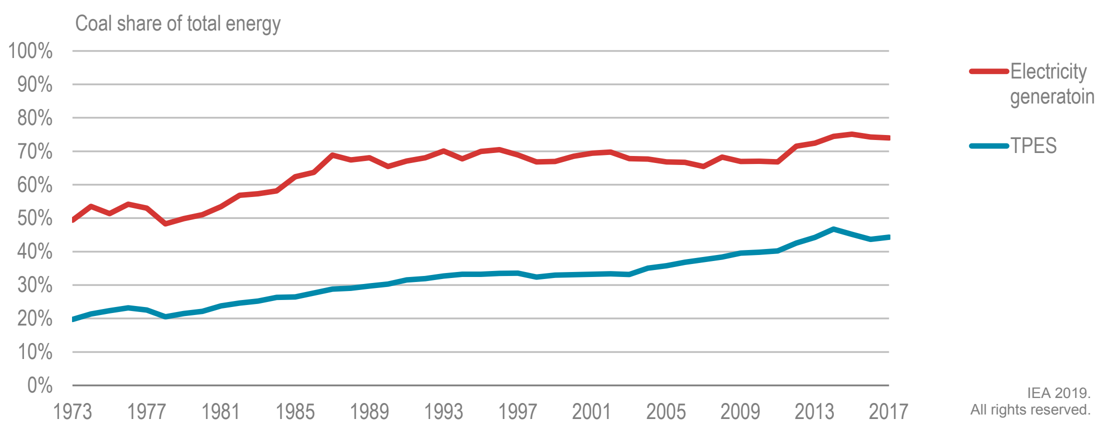
*India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. So, the statement: "In 2017 consumption was 937 Mt" refers to the data India has collected (and supplied to the IEA) from 1 April 2017 to 31 March 2018.

**Coke ovens and blast furnaces.

Overview

India is the world's second largest producer of coal after the People's Republic of China. The share of coal in both the energy mix and the power mix in India has been increasing since the 1970s (Figure 9.1), and in 2017 coal provided 44% of the total primary energy supply (TPES) and 74% of electricity generation. Coal is the most abundant fossil fuel resource in India, although Indian coal is generally of poor quality, with high ash content and low calorific value.

Figure 9.1 Role of coal in energy supply and power generation, 1971-2017



Note: Includes hard coal (anthracite and other bituminous coal) and lignite.

Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

With the nationalisation of India's coal industry in 1975, Coal India Limited (CIL) was set up as a monopoly to market coal and to manage the coal mines.[1] This decision reflected the need to have energy for economic growth, and a new appreciation of energy security after the first oil shock. Being the most abundant fossil fuel in India, coal was identified as the foundation of its energy supply. The nationalisation aimed to foster safety, mitigate frequent mining accidents and stimulate investment in the country.

In 1993 the coal production monopoly of CIL was partially broken with the allocation of captive blocks for power, iron and steel and, later on for cement, coal gasification and coal liquefaction. A decade later, in 2003, power sector reform triggered coal demand to rise rapidly in this sector. Over the years, however, coal production was not able to catch up with demand and CIL faced difficulties ramping up production, not only because of insufficient investment and productivity, but also because of barriers to production caused by delays in statutory clearance, notably to use land that was dedicated to afforestation. The coal demand–supply gap started increasing year by year, which was met through imports. With a view to developing and increasing domestic coal production, the Government of India (GoI) allocated 218 coal blocks to captive use. However, in 2014 the Supreme Court declared that the majority (204 out of 218) of the captive block allocation from 1993 was arbitrary and illegal, which brought production at those blocks to a halt. To auction these cancelled coal blocks through competitive bidding and to allocate the same to public-sector companies, in 2015 the GoI enacted the Coal Mines (Special Provision) Act and amended the Mines and Minerals (Development and Regulation) Act of 1957 and the Coal Mines (Nationalisation) Act of 1973.

Considerable progress has been made in building coal power plants and in ramping up coal production. Since May 2014, 52 new mines have been opened, adding over 160 Mt of mining capacity per year. Coal power generation has increased continuously in India since 1973, which has reinforced the role of coal in electrification and economic development, and explains why addressing the negative impacts of coal was not a priority, given the focus on increasing the supply of energy, in particular electricity generation.

Most of the coal consumed in India is domestic and a large share of it is transported throughout the country, sometimes over long distances. As coal supply has been scarce, the allocation of coal is regulated by the government to ensure supply is prioritised while reducing transport and logistics costs. Given that demand is scattered throughout India, this means that coal is mostly transported by the rail system. Transport of increasing amounts of coal over long distances has put pressure on the rail system.

Coal mining supports direct employment of around 500 000 workers. Considering direct and indirect employment, several million jobs are dependent on the coal industry. However, India has to deal with the environmental externalities linked to production and use of coal, which are equally abundant – its ecosystems are affected by mining, there is air pollution from coal use, impact on water at different stages of the production and consumption process, and the CO_2 emissions associated with coal burning. India's coal dependence is unlikely to disappear in the medium term and it is therefore a must for policy makers, industry and, more generally, Indian society, to minimise its negative impacts by using state-of-the-art technology in a cost-efficient way.

[1] The monopoly is not total anymore, as some public companies and private captive and commercial mines are allowed.

Today, the Indian coal sector is at a crossroads. On the one hand, the Indian economy is expected to grow considerably in the coming years, and so too are the three largest coal-consuming sectors: electricity generation, iron and steel and cement production. The prospects for the electricity sector are bright, driven by economic development, the increasing number of people with access to electricity and the growing middle class who will expand their use of air conditioners and other appliances. On the other hand, climate commitments made by India (within the framework of the Paris Agreement), air pollution, water stress in some areas and other environmental issues, and the declining costs of renewables, in particular solar photovoltaic (PV), impact the business case of the coal sector at large. The main certainty is that, given its central role in the energy and economy in India, a part of India's success in the future is linked to the successful and efficient management of the coal sector.

Supply and demand

Resoures and reserves

According to the latest Geological Survey of India of April 2018, India holds proven coal reserves of 148.79 gigatonnes (Gt) and total coal resources[2] of 319.02 Gt. The proven lignite reserves amount to 6.54 Gt, while total lignite resources are 45.66 Gt.

Most of the hard coal in India is bituminous coal, with some sub-bituminous reserves. Indian coking coal has a high ash content, is mostly used for thermal purposes and is generally not suitable for the production of metallurgical coke. The regional distribution of reserves mirrors the production profile (see below). Most of hard coal resources are located in seven States: Jharkhand, Odisha, Chhattisgarh, West Bengal, Madhya Pradesh, Maharashtra and Telangana. And lignite resources are concentrated in three states: Tamil Nadu, which accounts for 80% of lignite resources, Rajasthan and Gujarat.

To support exploration of coal and lignite, the GoI plans to spend INR 7 billion (USD 50 million) in 2018/19 and around INR 10 billion (USD 72 million) in 2019/20.

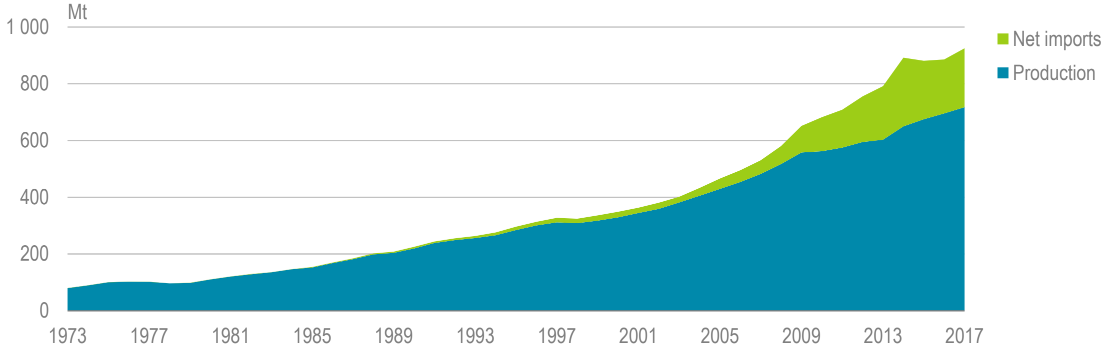
Domestic production

Coal production in India has been increasing over recent years (Figure 9.2). In 2017 coal production totalled 726 Mt, of which 635.6 Mt was thermal coal, 47.5 Mt lignite and 40.9 Mt coking coal.

Almost 94% of the production is open pit, with the balance mined in underground mines. Production costs in India are INR 1 200/t (USD18/t) on average, lower than in most countries, even adjusted for quality, as the country has low strip ratios.[3] Average costs are very much dependent on the performance of CIL, which accounts for 80% of domestic production (with an average cost of INR 1 176/t). However, production growth has not been able to keep up with demand growth, especially since the electricity sector reform of 2003, leading to increasing domestic coal supply shortages and imports (Figure 9.2).

[2] Resources refers to fields that are potentially valuable, and for which reasonable prospects exist for eventual economic extraction. Mineral reserves are valuable and legally, economically and technically feasible to extract.
[3] Strip ratio refers to the overburden (m^3) removed to extract 1 tonne of coal. India has a ratio below 3 on average.

Figure 9.2 Coal supply by source, 1973-2017



Note: Includes hard coal (anthracite and other bituminous coal) and lignite.
Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Hard coal production in India is concentrated in four states – Odisha, Chhattisgarh, Jharkhand and Madhya Pradesh – which account for almost 80% of production. Other producing states are Telangana, Maharashtra and West Bengal, with smaller volumes produced also in Uttar Pradesh, Meghalaya and Assam. Jharkhand is the largest producer of coking coal. In 2015, out of 60 Mt of coking coal produced, only 6.1 Mt was sold as washed coking coal for metallurgical purposes.[4] High-ash coal, i.e. coal with a low calorific value (CV), is predominant in India, with 70% of domestic supply in the CV range of 3 400-4 600 kilocalories per kilogram (kcal/kg) GAR (gross as received). This is lower quality than the international standards, especially seaborne-traded thermal coal, which is typically in the range of 5 000-6 000 kcal/kg NAR (net as received).[5]

Lignite production in India (around 47 Mt in 2017) is much smaller than hard coal, and it is produced mostly in three states: more than half in Tamil Nadu and less than one quarter each in Gujarat and Rajasthan.

Imports

To satisfy growing coal demand amid production shortages, imports have been increasing for two decades, reaching 209 Mt in 2017. During the period 2014-16 the push for additional domestic production and new mines, together with some moderation of demand growth, resulted in a temporary decline in imports.

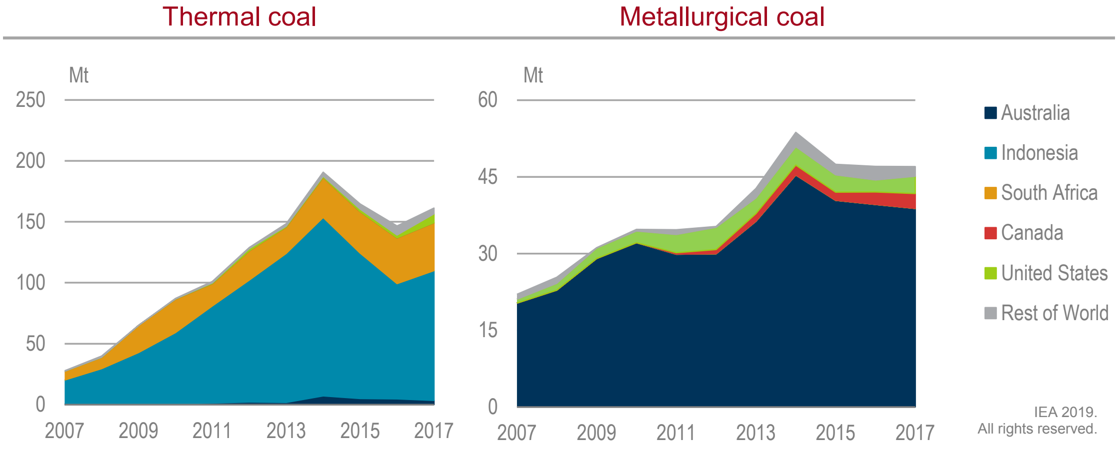
Australia supplies most of India's metallurgical coal imports (2017). Indonesia and South Africa are the import sources for thermal coal, and Indonesia provides 65% of thermal coal imports and Africa 25% (Figure 9.3). Other major suppliers are the United States, Mozambique, the Russian Federation and Canada.

Imports are not only the result of the consumption–production gap, but also related to other factors. First, the scarcity of low-ash coking coal in India requires imports to produce metallurgic coal for rising iron and steel production. Second, many coal-fired power plants

[4] Some of the high-ash coking coal has being reclassified as non-coking in recent years and, therefore, coking coal production data need to be properly interpreted.
[5] This is approximately 5 300-6 300 kcal/kg GAR.

that are located along the coast (see Table 9.1) are designed to use imported coal and, therefore, the quality of domestic coal is not suitable for those plants. Third, some plants blend domestic and imported coal to achieve a better quality, increase efficiency and reduce pollutant emissions. And fourth, imports are necessary when incremental demand by coal consumers for higher supplies cannot be honoured by CIL due to logistical bottlenecks or price discrepancies.

Figure 9.3 India's coal imports by source, 2007-17



Source: IEA (2018a), *Coal 2018*.

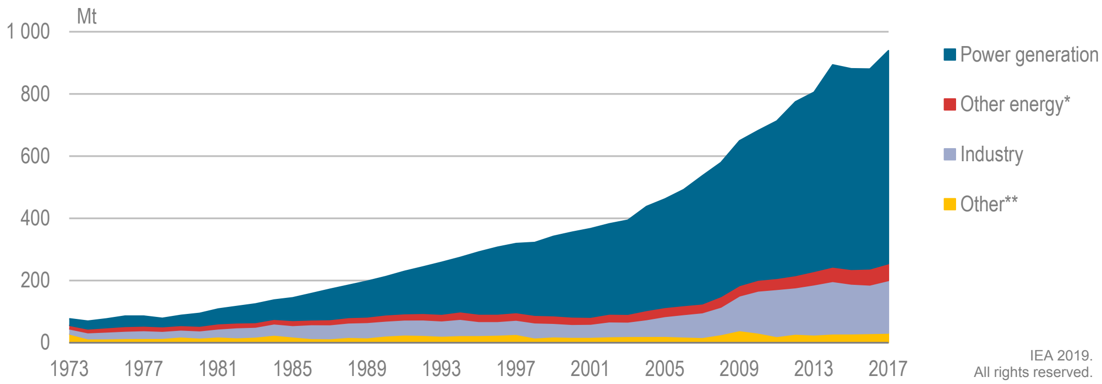
Coal consumption

Power and heat generation account for over two-thirds of coal consumption (three-quarters in terms of weight), followed by iron and steel production (almost 20%), cement (around 5%), and other industries like fertilisers, pulp and paper, non-ferrous metals and chemicals production, as illustrated in Figure 9.4. In 2017 residential and services coal use was 3.3%.

In 2018 India surpassed Japan as the second-largest steel producer in the world (with total steel production of 106.5 Mt). Around 55% of the steel in India is produced in electric arc furnaces and the remainder in oxygen-blown converters. India is the world's largest producer of direct reduced iron, also known as sponge iron, accounting for more than one-third of global production (or 30.3 Mt in 2018). India was the third-largest producer of pig iron in the world after the People's Republic of China ("China") and Japan, with a total production of 71.5 Mt in 2018.

Power generation, the largest consumer of coal, has various characteristics: India has coastal (31 GW) and inland plants (159 GW), which are usually located close to mines. India has 18 GW of power plants that are designed to only use imported coal (Table 9.1). Power plants with a total capacity of 32 GW use a blend of domestic and imported coal. Plants using only domestic coal have a total capacity of 140 GW.

Figure 9.4 Coal consumption by sector, 1973-2017



*Mainly coke ovens and blast furnaces.
**Includes agriculture, forestry and fishing.
Notes: Includes hard coal (anthracite and other bituminous coal) and lignite. TPES of coal by consuming sector.
Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Table 9.1 Plants designed to consume imported coal

Name of plant	State	Company	Capacity (MW)
JSW Ratnagiri	Karnataka	JSW Energy	1 200
Mundra TPS	Gujarat	Adani Power	4 620
Mundra UMPP	Gujarat	Coastal Gujarat	4 000
Sikka	Gujarat	GSECL	500
Trombay	Maharashtra	Tata Power	1 250
ITPCL	Tamil Nadu	IL&FS	1 200
Muthiara	Tamil Nadu	Coastal Energen	1 200
Torangallu I	Karnataka	JSW Energy	260
Torangallu-II	Karnataka	JSW Energy	600
Udupi	Karnataka	Adani Power	1 200
Salaya	Gujarat	Essar Power Gujarat	1 200
Thamminapatnam	Andhra Pradesh	Meenakshi Energy	200
Simhapuri	Andhra Pradesh	Simhapuri Energy	600
Total			18 030

Note: Assuming 5 500 kcal/kg coal, 38% efficiency and a plant load factor of 70%, these plants require around 45 Mt of coal per year.

The National Thermal Power Corporation (NTPC) is India's largest coal power generator and one of the largest in the world, with 52 GW of installed coal generation capacity. Utilities owned by the state governments hold another 59 GW, while independent power producers (IPPs) account for 75 GW. Different public joint ventures in which NTPC is present account for 5 GW. Additionally, there are captive power plants with a total capacity of 54 GW, which produce electricity for own use in certain industries (steel, aluminium, cement and fertilisers).

India has 50 GW of capacity under construction, with 50% being supercritical, while among installed capacity less than one-third is supercritical. India's subcritical coal-fired fleet is relatively young at 15 years old on average.

Coal power generation has grown at an astonishing rate of 8% per year during the past decade, surpassing the robust growth of 6.5% in power demand, which was strongly driven by the Electricity Sector Reform of 2003. In 2017 the share of coal in power generation reached a historic peak of 73%, while average plant load factors have been below their technical capacity for several years, leaving a large part of the fleet underutilised (see also Chapter 7 on electricity). Besides operational issues, a low plant load factor has economic implications for the recovery of investment costs. Around 55 GW of coal power plants in India are under severe financial stress, including many state-owned plants, for which tariff revenues very often do not cover generation costs. Private plants are struggling to conclude power purchase agreements (PPAs) and fuel supply agreements (FSAs). These non-performing assets in the power system have become a problem for the financial sector, as many of them have not repaid their loans.

India's Central Electricity Authority (CEA) monitors stocks at 114 coal power plants, and classifies them as critical if they are less than seven days of consumption for non-pithead plants or five days for pithead plants. Supercritical means that stocks are less than four days of consumption for non-pithead plants or three days for pitheads plants. CEA announced in March 2019 that for the first time since 2014 no plants are facing critical or supercritical stock levels.

Institutional framework

The public sector

The Ministry of Coal (MoC) is central to the performance of the coal industry. It has overall responsibility for determining policies and strategies in respect of the exploration and development of coal and lignite reserves to secure their availability to meet the country's demand. This includes sanctioning important projects of high value and the clearance of all related issues. Jointly with the Ministry of Environment, Forestry and Climate Change (MoEFCC), a key mission of the MoC is to ensure that the development of the coal sector takes place in an environmentally friendly and sustainable manner.

The Coal Controller's Organisation, a subordinate office of the MoC, ensures: a) proper coal sampling and maintenance of grades produced by the collieries; b) collection of certain duties levied on coal dispatched; and c) collection and production of coal and lignite statistics, and other coal-related tasks. The Ministry of Railways plays a critical role in ensuring rail capacity and setting the price for the transport of coal. State-owned Indian Railways transports the majority of coal. The Geological Survey of India carries out fundamental research, jointly with other public bodies, such as the States' Directorates of Geology and Mining. Detailed exploration is done by the Central Mine Planning and Design Institute, a subsidiary of CIL, either directly or through private entities, together with States'

Directorates of Geology and Mining. Some companies conduct exploration themselves in their command areas.

The role of the government in India's coal sector is underpinned by the presence of state-owned companies along the value chain. Coal production is dominated by state-owned mining companies, responsible for 82% (600 Mt) of the country's coal output in 2017, mostly CIL and others. The largest coal consumer is NTPC. Bharat Heavy Electricals Limited (BHEL) is the largest manufacturer of coal boilers in India.

CIL is a public company. The GoI holds 70.96% of CIL's shares, while the remainder is held by the public. CIL accounts for 80% of total coal production in India and is central to the GoI's strategy to increase coal production for economic growth, adequate electricity supply and revenues for the budget through dividends. CIL has around 300 000 employees. In 2017 it had 394 mines, of which 193 were underground mines, 177 were opencast mines and 24 were mixed mines. Given its higher capacity and productivity, opencast production accounts for 95% of CIL output. CIL produced 567 Mt in 2017, which it sells mostly under long-term contracts but also through some internet auctions. A total of 120 mining projects with a production capacity of over 500 Mt per year are under development. CIL is the largest producer in the world by tonnes of coal produced.

Singareni Collieries Company Limited is a public company with operations that date back to the time before the nationalisation of the coal industry in the 1970s. It preserved its status after CIL was established and is owned by the government of Telangana (51%) and the GoI (49%). The company operates in Telangana state, producing 62 Mt of coal and giving jobs to over 50 000 employees.

NLC India Limited, formerly Neyveli Lignite Company, is a state-owned company with almost 10 000 employees. In 2017 it produced 27.6 Mt of lignite and also owns the adjacent power plants generating 22.3 TWh (2017) of electricity. Its expanding business plans aim to develop the company from a pure lignite player to an investor in both hard coal and lignite, as well as power generation. In order to achieve this, NLC and CIL have signed a joint venture to build both solar and coal power generation capacity.

Several other public companies produce hard coal. **NTPC**, a state-owned company with the Maharatna status, has recently become a coal producer in addition to being the largest utility in India. As part of the GoI's effort to ramp up domestic production to guarantee adequate supply and reduce imports, NTPC has received 10 coal blocks with geological reserves of over 7.3 Gt. In 2018 NTPC produced 7.3 Mt of coal (jumping from only 2.7 Mt in 2017) from its operations in the Pakri Barwadih mine in Jharkhand (6.8 Mt) and the Dulanga mine in Odisha (0.5 Mt). NTPC plans to continue expansion in the coming years.

Rajasthan Vidyut Utpadan Nigam Ltd (RVUNL), owned by the government of Rajasthan, produces from its captive mines around 7 Mt per year to partially feed its thermal power capacity of over 6 GW. India's large iron and steel producers also produce coal from their captive mines, such as Steel Authority of India Limited and its subsidiary the Indian Iron and Steel Company, the Damodar Valley Corporation, Jharkhand State Minerals Development Corporation Limited and J&K Minerals Limited. Among the small lignite producers, several states own power generation with captive mines in Gujarat, Rajasthan and West Bengal.

The private sector

The private sector consists of companies to whom coal blocks were allocated to develop captive mines. The main producers are: Sasan Power Ltd, producing over 15 Mt from its Moher and Moher-Amlohori Extension mines for its 4 GW coal power plant in Madhya Pradesh; Tata Steel, producing around 6 Mt from Jharia and West Bokaro mines in Jharkhand; and Jaiprakash Ventures Ltd, producing over 3 Mt from Amelia North mine for its Jaypee Nigrie Thermal Power Plant, in Madhya Pradesh.

Government policies

India's coal sector is progressively moving towards market-based approaches with competitive auctions of coal mines and linkages, although it is still regulated all along the coal supply chain.

Royalties and levies

Coal is a major contributor to the public budget. A part of CIL profits are paid into the public budget through dividends. Levies and royalties on coal production are also a source of revenues for the central and state governments. The clean energy levy has been levied on coal since 2010 – the so-called coal cess – which reached INR 400/t (USD 5.78/t) by 2016. In 2017 the general good and services tax (GST) was introduced subsuming different pre-existing taxes, simplifying the tax regime and reducing the tax burden for coal.

The cess revenue was initially allocated to the National Clean Energy and Environment Fund (NCEEF) to invest in clean energy projects and technologies. As such, the cess revenues accounted for a large part of the budget of the Ministry of New and Renewable Energy. The GST did not replace the INR 400/t environmental cess and some other taxes, such as forest, environmental or terminal taxes charged by some of the states. Only the NCEEF was abolished; revenues from the cess now flow into a fund to compensate companies for the impacts stemming from the GST reform. Coal production and imports are therefore subject to a coal compensation cess of about USD 6/t coal.

Commercial mining

India is introducing commercial coal mining – the most radical reform since the nationalisation of the coal sector in the 1970s. Since the amendment (Special Provisions) of the Coal Mines Act in 2015, which formally ended the marketing monopoly of CIL, private companies can develop new mines based on government auctions of unallocated coal mines/blocks. Private companies can sell coal in the free market without price or end-user restrictions. The Cabinet Committee on Economic Affairs (CCEA) approved the auction methodology in February 2018, which marked the start of commercial mining. The methodology provides for an ascending forward auction whereby the bid parameter will be the royalty per produced tonne of coal to be paid to the state government. The floor price will be determined in accordance with a methodology established in 2014.[6] Public power plants were excluded from the competitive bidding; however, in a separate

[6] Sl No. 1 of Ministry of Coal's order no. 13016/9/2014/CA III dated 26 December 2014.

process they were able to receive guaranteed supplies in the recently reallocated coal fields (41 out of 89).

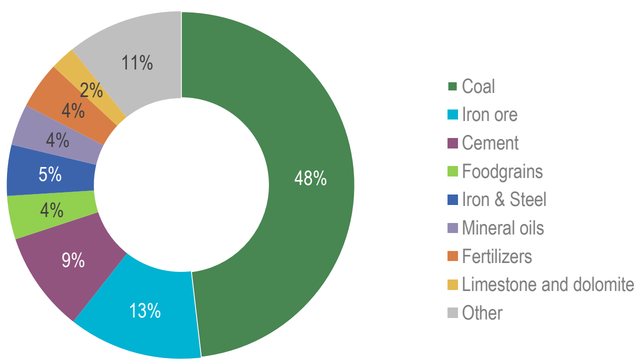
After the cancellation of two round of auctions, in December 2019, the GoI carried out the auction of coal blocks and allocated five blocks (to Birla and Vedanta). In 2019 the GoI also approved changes to allow captive coal producers to sell up to 25% of their production in the open market without any price restriction. Foreign companies are allowed to own and operate coal washeries (without coal mining investment). In September 2019 the GoI ruled that coal mining will also be fully open to foreign companies, as the country aims to increase the amount of foreign direct investment in the coal sector.

Coal and railways

India's coal reserves are mostly located in the east, while many of the coal-fired power plants are in the consumption centres of the west and centre, far away from the mines. Coal and railways are strongly interdependent in India, as most coal is transported by rail (60%) and coal is the leading product shipped on the rail network, which is heavily congested at times, resulting in delays of delivery. Coal accounts for 40% of Indian Railways' revenues. In short, rail transport is a large element of coal delivery costs and coal freight is a major part of rail revenues. In contrast to international practice, freight tariffs in India are higher than passenger tariffs; in fact they were the highest in the world on a purchasing power parity basis. Moreover, whereas rail bottlenecks are sometimes responsible for coal shortages, coal is also the main culprit for the saturation of the rail system. In 2017 coal haulage accounted for about 40% of the freight transported by Indian Railways on a tonne-kilometre basis and for 48% on a tonne basis (Figure 9.5).

In recent years, the total volume of coal moved by rail has continued to grow (albeit at a slower rate than in the past), while the average distance that coal is moved has declined. This is mainly due to the rationalisation of the coal supply chain to cut costs and to the construction of new coal-fired power plants closer to the eastern area (where most coal is produced) and nearer to coastal areas (where import centres are located).

Figure 9.5 Transport of bulk commodities by Indian Railways, 2017



Note: The metric used in this figure is goods lifted, which describes the weight of goods carried and is measured in tonnes.

Source: IEA based on Indian Railways (2018a).

Given the important role of coal in the freight mix carried by Indian Railways, stagnation of transported coal volumes in combination with the declining average distances has led to a decline in total rail freight activity (measured in tonne-kilometres).[7] Another important aspect of the interdependence between coal and railways is that rail freight (primarily coal haulage) cross-subsidises passenger fares. To fulfil the vision of railways as the lifeline of the nation connecting all of India, passenger fares are kept low, which results in charges for freight rail transport that are significantly higher than in other countries,[8] especially over the past five years.

In the longer term, the cross-subsidy is expected to become economically problematic, according to the Base Scenario laid out in *The Future of Rail* (IEA, 2018b). Comparing the 2017-50 increase in total freight rail activity (160%) with the rise in activity of intercity trains (200%) might mean that rail freight generates insufficient revenues to continue to subsidise the passenger rail sector. A further increase in freight rail fares is unlikely to help, as this would further jeopardise the competitiveness of rail freight transport vis-à-vis road freight, or the competitiveness of coal itself.

Coal supply allocation and pricing

Most coal is sold to consumers through long-term FSAs at prices set by CIL. There is one price range for power utilities, including IPPs, fertilisers and the defence sector, and another price range (around 20% higher in the most popular grades) for non-regulated sectors.[9] Given coal shortages, public power plants receive priority in coal allocations from CIL, while IPPs need to purchase coal on the spot market.

In order to value coal with regard to its quality, India has 8 grades for coking coal, 2 for semi-coking coal and 17 for non-coking coal. Ash content for coking coal, ash and moisture for semi-coking, and CV for non-coking coal are the parameters relevant to set prices. Until 2011 non-coking prices were set based on the useful heat value (UHV), which was determined by a standard calculation that related useful heat to real CV. In 2011 the government changed to gross calorific value (GCV), more in line with international standards and the real value of coal sold.

CIL supplies between 10% and 20% of its coal through spot and forward e-auctions for different sectors, since electronic auctions were introduced in 2007. In general, prices resulting from the e-auctions are higher than regulated prices – sometimes much higher, even double – owing to market tightness. To address frequent disputes between producers and consumers about the actual quality of the coal delivered, third-party sampling has been established as a means to ensure the quality of coal supplied by the producers. The third party, generally a reputed institution, collects a sample, which will be analysed in the lab. Three more samples are given to the producer, consumer and a referee. In this way, the confidence that the end user is paying for the quality that it consumes has been re-established.

As coal supplies in India are not enough to satisfy demand, and imports cannot be used by all power plants and are more expensive, the GoI has to allocate the scarce coal capacity. To save transport costs and rationalise coal supply logistics, the government encourages buying coal from mines that are closer to the power plant through so-called

[7] A tonne-kilometre is a measurement of freight activity, defined as one tonne of (bulk) goods being shipped over one kilometre.

[8] The fare-to-freight ratio (defined as the ratio between revenue per passenger-kilometre and revenue per tonne-kilometre) in India is about 0.24, well below the 0.7 to 1.9 range observed elsewhere (Kamboj and Tongia, 2018).

[9] Prices for coal from Western Coalfields Limited subsidiary are a little higher than the general price.

linkages – this means coal allocation is done by plant and is fixed. India's New Coal Distribution Policy of 2007 regulated coal supplies to the power and non-power sectors through these linkages, based on the recommendations from the ministries and approval by the Standing Linkage Committee for Power, Sponge Iron and Cement Sector. Since 2016, linkages to the private sector have been auctioned with contracts of five years, extendable once. Existing FSAs were not renewed, with the exception of the central public-sector entities and the fertiliser sector, leaving many without coal supplies from CIL (notably captive power plants) with only one option: to bid for supplies.

As the power market evolved, with an increasing number of private generators, the coal allocation and pricing policy came under pressure. In 2017 the GoI introduced the Scheme for Harnessing and Allocating Koyla (Coal) Transparently in India (SHAKTI) to auction off coal linkages for power assets that had power purchase agreements (PPAs), but no fuel supply agreements (FSAs). The IPPs participating in the auction had to offer a discount in their PPAs. The CEA designs and issues the methodology for coal linkage allocation, which states follow when awarding the linkage (through their DISCOMs) according to applicant's need, efficiency and cost of power to the power plants in its territory, including the private sector. Allocations to the private sector are made through auction. In March 2019, SHAKTI was amended to further flexibilise coal supplies and auctions to deal with the power assets under financial stress.

State-owned power plants with long-term FSAs and coal linkages (the regulated sector) were not able to trade on the power exchanges, thus preventing DISCOMs from improving their generation portfolio in terms of cost and adequacy. In 2019 the government announced a new flexibility package, including the possibility for the power plants to participate in electricity market exchange using coal from CIL and for the state DISCOMs to share FSAs with private companies.

During the period 2014-17, the Central Electricity Regulatory Commission (CERC) allowed power plants that received coal under SHAKTI and the New Coal Distribution Policy to seek a compensation for the additional cost of coal procured from alternative sources because of the failure of CIL to supply.

Coal washing

Washing is the process of reducing ash content in raw coal, most commonly using density to separate more heavy ash from lighter coal, besides other more sophisticated and expensive ways of washing.

India's high-ash and low-CV coal causes high operational, transport and maintenance costs for coal users. Benefits of washing include better heat transmission and plant efficiency, less boiler corrosion, lower ash disposal requirements and lower emissions of air pollutants, as well as lower weight and transport costs. While coal washing is beneficial, as it reduces costs and also some CO_2 emissions, it also has some drawbacks. First, washing increases capital costs, as it requires investment to build and operate the washery (supplies, power and labour costs). Ash separation is not perfect and washing produces by-products, such as washed coal, middlings and rejections, thus losing part of the energy contained in the raw coal.

In a country such as India, where prices are regulated and different prices apply to different coal grades, price regulation needs to incentivise washing. The government banned the transport of coal with ash content higher than 34% over more than 500 km. Historically, no comprehensive effort has been made to develop equipment for coal washing, resulting in the use of foreign equipment inappropriate for Indian coal. More recently, CIL and the MoC have sponsored several R&D programmes and currently most of the equipment available for washing coal in India is suitable. Despite the improvement, an effort to build further washing capacity and develop washing technology specific for Indian coal would pay off, considering the specific characteristics of Indian coal and the prospects for long-term utilisation of coal in India.

CIL operates 15 coal washeries, with a capacity of 37 Mt per year, of which 12 are for coking (23 Mt per year) and the others are for non-coking (14 Mt per year, compared with over 500 Mt of annual production). CIL plans to build 9 new washeries for coking coal and 9 non-coking washeries to add more than 93 Mt per year of washing capacity.

Washing is not an option for coking coal used for metallurgical purposes, but instead an obligation, as the steel-making process requires low-ash coal to produce coke suitable for use in the blast furnace.

Local air quality policies

By international comparison, India has some of the highest levels of air pollution, caused by a range of different local sources (see Chapter 3 on energy and sustainable development). Burning solid fuels like firewood and dung-cakes at home is a major source of pollution, besides emissions from transport, crop burning and construction. Coal use in power generation is another large emitter, responsible for 60% of industrial particulate matter (PM) emissions, 45% of sulphur dioxide (SO_2) emissions and 30% of nitrogen oxide (NO_X) emissions (CSE, 2018).

In order to reduce adverse effects of thermal generation on the environment, the GoI has adopted stringent environmental norms for air pollutants and water consumption.

In order to decrease pollution from coal power plants, in 2015 the MoEFCC adopted standards to limit the concentration of SO_2, NO_X, PM and mercury in stack emissions for coal-fired power plants. Existing plants were to meet the standards within a period of two years (by December 2017). These standards were amended in 2018.

Around 150 GW of thermal capacity (out of the total coal fleet of 194 GW), involving 400 units, needed to install air quality control systems. By the expiry of the deadline in 2017, no existing plant had complied with the standards and the government postponed the implementation deadline to 2022. The Supreme Court ruled that the implementation should ensure that the most-polluting plants comply by 2021, while at the same time postponing the further tightening of the standards. The 2015 standards specified the further tightening of air pollution limits for NO_X and SO_X emissions (with NO_X limits falling to 300 milligrammes per normal cubic metre [mg/Nm^3] and SO_X to 100 mg/Nm^3). In August 2019 the Supreme Court annulled this tightening of SO_X and NO_X emission limits.

In December 2017 the CEA published the implementation guidelines for air quality control systems. It prepared a phasing plan for the implementation of the standards at identified thermal power plant units: 66 GW of output requires the augmentation of electrostatic precipitators (to meet PM limits) and 166 GW the retrofitting of flue-gas desulphurisation and combustion modification/optimisation, with other plants upgraded in collaboration with the Regional Power Committees. As of March 2019 tenders had been issued for the installation of flue gas desulphurisation in around 96 GW of capacity, more than half of the capacity requiring this retrofit (IISD, GSI and CEEW, 2019).

The cost of implementing the standards is estimated at USD 12 billion. The GoI ruled that the investment costs of retrofitting pollution control installations and the associated operational costs can be passed on to utilities and consumers by the State Electricity Regulatory Commissions. Despite this regulatory clarity, the practical implementation is challenged by the poor financial health of the DISCOMs and consumers. Declining capacity load factors and the financial stress of the state-owned DISCOMs and some of the IPPs (see the Chapter 7 on electricity) has left the power sector with poor financial health. This is considered to be a significant barrier to passing on the costs to consumers and swiftly implementing the pollution limits. In 2019 the Ministry of Power proposed to the Ministry of Finance a financial subsidy package of USD 11.2 billion in order to avoid power price increases.

The benefits of compliance to public health outweigh the costs by far. Moreover, there are benefits in using by-products of the air quality control systems, both economical and environmental, as fly ash is a valuable product that reduces the CO_2 footprint of cement making. Another by-product, gypsum, can be used in construction, reducing the environmental footprint compared with using gypsum mined from a quarry. If met, these emission standards would reduce pollution in India substantially, at low costs by international comparison.

While air pollution is the main environmental problem of coal power plants in India, it is not the only one. Water pollution and consumption by thermal plants is another one. The MoEFCC notified new environmental protection rules with stricter limits for water consumption from existing, constructed and new thermal power plants. Plants built after 2017 shall not exceed water consumption of 3 m^3/MWh and existing plants not more than 3.5 m^3/MWh. Plants installed after 2017 are required to achieve zero waste water discharge. Better management of pollutants, higher efficiencies and dry air cooling will help this.

India's climate commitments and the role of coal

India's National Determined Contribution (NDC) under the Paris Agreement sets out plans to reduce the emissions intensity of the economy by 33-35% by 2030 from 2005 levels; to reach 40% of power generation capacity from non-fossil fuels; and to create an additional carbon sink of 2.5-3 billion tonnes of CO_2 equivalent through additional forest and tree cover. The GoI has expressed certainty on reaching at least the two energy-related targets sooner than 2030. Thanks to progress made in the implementation of these targets, the emissions intensity of India's gross domestic product has already decreased by around 20% over the past decade (2005-15). At the same time, total energy-related CO_2 emissions are expected to rise.

The National Electricity Plan of India of 2018 included plans to build 94 GW of new coal-fired capacity (mainly supercritical coal units) between 2017/18 and 2026/27 (CEA, 2018). However, to date only 22 GW have been permitted amid weak economics, while 50 GW are under construction. Given the slow progress, the CEA's 2018 plan did not foresee the construction of any additional new coal plants. However, the CEA has outlined in its draft

2019 generation optimisation plan a large potential investment in new coal plants up to 2030 (105 GW of pithead plants and 44 GW of load-centred plants) (CEA, 2019).

The 2018 National Electricity Plan includes a new target for the closure of 48.3 GW of end-of-life coal plants. Specifically, the plan forecasts the closure of the oldest 22.7 GW of coal power plants up to 2021/22. This would include 5.9 GW of normal end-of-life retirements and 16.8 GW of early closures because of non-compliance with air quality regulations. An additional 25.6 GW of coal capacity is being considered for early retirement in the five years from 2021/22 to 2026/27.

India's power system is experiencing rapidly rising shares of variable renewable electricity, which has two different impacts on the economics of existing coal power plants. On the one hand, it means less generation from these plants will be needed, which brings more economic and financial stress for many producers. On the other, flexibility requirements of the electricity system will rise. Many coal plants in India were not designed to follow load, but to provide baseload power. The GoI is currently identifying the plants that can and need to provide such flexibility. The deployment of other sources of flexibility, such as natural gas, pumped hydro storage or nuclear remain below expectations. The implementation of the new power market reforms are important to support flexibility and CERC has proposed reforms of ancillary services and short-term markets and economic dispatch (see Chapters 7 and 8 on electricity and system integration).

Carbon capture and storage

In 2007 the Department of Science and Technology initiated a national programme of research into carbon sequestration (carbon capture and storage [CCS]). R&D in CCS is being pursued by CSIR laboratories and academic institutions under the programme.

As part of Mission Innovation, India has initiated a funding opportunity in the Carbon Capture Innovation Challenge (IC#3) for joint R&D in the field of CO_2 capture, separation, storage and CO_2 value-added products to be taken up jointly by Department of Biotechnology and Department of Science and Technology with member countries of Mission Innovation.

The Intergovernmental Panel on Climate Change special report on CCS identified the need to obtain much more information on storage capacity in India (IPCC, 2005). Large areas of the Indian subcontinent may not be suitable for onshore CO_2 storage due to high seismic activity and population density, and any CO_2 storage activity would need to protect subsurface aquifers, which are vital source of ground water for agriculture.

NTPC's Energy Technology Research Alliance (NETRA) initiated a project with IIT Mumbai to establish a 10 MW equivalent plant to capture flue gas CO_2 and use it in the production of soda ash, urea or methanol. NTPC-NETRA signed a memorandum of understanding with India's Oil and Natural Gas Corporation (ONGC) to establish a carbon capture plant at NTPC Jhanor Gandhar gas-fired power plant and the utilisation of CO_2 in enhanced oil recovery in ONGC's Jhanor field.

Assessment

An efficient coal sector – from mining, through cleaning and conversion, to utilisation and waste product management – is critical not only for electricity generation, but also for industrial development (steel, cement, fertilisers and others). This requires proper market functioning and clean production and use of coal. The government has to balance the significant employment and societal benefits of coal with environmental concerns and other challenges. India is working towards these goals with a number of important reforms in recent years. The GoI should foster the implementation, enforcement of, and compliance with, high safety and environmental protection standards across the entire coal chain.

India's coal supply has increased rapidly since the early 2000s and coal continues to be the largest domestic source of energy and electricity generation. Between 2003 and 2014 total coal supply grew by 8.5% per year on average. In 2016 domestic coal production (hard coal and lignite) accounted for 71% of total coal supply. The remaining 29% was imported, as India's thermal coal is generally not of high quality nor is there a large quantity of coking coal.

In 2017 the upward trend for India's coal production continued. However, the growth in domestic production was not enough to meet the increased demand for both thermal coal and metallurgical coal. Coal imports therefore rebounded in 2017, and India became the world's second-largest coal importer. Indonesia, South Africa (thermal coal) and Australia (metallurgical coal) are the largest sources of India's coal imports.

India's coal market is going through important changes. In February 2018 the GoI approved the methodology to allocate coal blocks for commercial mining, which will end the monopoly held by state-owned CIL on coal production and sales. The start of commercial mining generates great hopes, including among the energy-intensive industries, but also resistance by others, mainly the trade unions. More than one year after the 2018 decision, a number of open issues remain unresolved, delaying the implementation of the decision. The GoI is expected to issue bidding rules for commercial coal mine auctions of around 200 mines for the next five years.

The profitability of the blocks to be auctioned is one of the major issues. A point of attention is the size of the blocks on offer; if they are too large, some potential bidders will be deterred. The size of the reserves, their quality and geological conditions, which might allow a cost-competitive exploitation of the blocks, are key parameters that investors need to know and assess. However, the delays and complexities related to land, forest and environmental permissions and dominance of long-term FSAs do not encourage private players to commit to the large investments required to develop a coal block.

Although commercial mining and the opening up to foreign investors have the potential to bring competitiveness, investment and new technologies to the coal mining sector in India, the main issues that CIL faces to expand production (i.e. land access, forest clearance or permit approval) will also be there for private producers. It is therefore critical that India continues its efforts to identify and properly assess coal reserves in its geography and streamline the permitting, land acquisition and environmental rules, for instance by creating a one-stop-shop.

Coal transport by rail from the mines to consumption centres has traditionally been a major challenge for coal producers in India. The level of coal freight charges is high and revenues are used to subsidise passenger transport. Reforms are needed to gradually phase out the cross-subsidy, while at the same time solidifying Indian Railways' role as an affordable transport service provider. There are several ways in which the GoI could promote a process of rationalisation, which would be beneficial for both the rail system and the coal sector. One action would be to complete the construction of the two dedicated freight corridors, with the eastern one being mainly dedicated to coal haulage. This completion of the corridors would have two beneficial effects on the overall Indian rail network. First, it would relieve traffic and reduce bottlenecks on existing lines, making way for new intercity passenger rail traffic. At the same time, it would increase the speed of coal haulage by rail and the overall efficiency of the coal supply chain, possibly leading to an increased share of coal haulage by rail.

Given that cross-subsidy leads to market distortions and unfair distribution of cost burdens, the government should target its phase-out. This could be supported by generating additional revenue by simultaneously increasing the attractiveness of passenger services and reducing the dependence of passenger rail services on cross-subsidy from freight rail. This can be achieved in a variety of ways, but the balance of operational costs and revenues needs to improve by diversifying the offer of intercity rail services (such as offering overnight connections). Another way to proceed could be to set differentiated fares and services, accounting for the prices of competing modes at different times of the day and for the origin and the destination of trips. A more creative way to proceed would be to increase non-fare revenue from rail stations and neighbouring areas through real estate development and land value capture, both for new stations (which should be large enough to be able to host commercial activities) and existing stations (through refurbishment and renovation).

Generally, Indian coal is of low CV as it contains a high percentage of ash. To improve coal quality and reduce transport costs, coal can be washed. Indeed the government requires coal to be washed if it is transported over more than 500 kilometres and contains more than 34% of ash. Due to current coal pricing system and lack of incentives, coal washing and technological development has not advanced as desired. Despite the progress in recent years to set up new washeries, there is room for further improvement in both washing capacity and technology.

Most coal in India is used for power generation. In 2017 power generation accounted for two-thirds of total coal demand, followed by industry, accounting for 24%, and small shares in the service sector (2%) and residential sector (1%). Among industries, the iron and steel industry is the largest coal-consuming sector, and increased cement production also contributes to the growth in industrial coal consumption. Coal dominates electricity generation in India, and has increased at a very high rate for several decades to reach 74% in 2017. Coal power generation has more than doubled over the past ten years, with an average annual growth rate of 8%, driving the increase in total electricity generation. Coal used in power generation has increased rapidly alongside the growth in electricity demand. India's coal-fired power plants have mostly been built since the opening up of the electricity market over the past 15 years and are thus relatively new.

Coal-fired power plants and industrial users have been traditionally supplied through long-term contracts, the so-called FSAs, with the mining companies. Recent policies – including e-auctions by CIL, and the auctioning of linkages and coal – aim to increase supply flexibility and reduce the tenure of FSAs. Irrespective of the benefits of the measures introduced to give more flexibility and solve issues through market-oriented mechanisms, when the underlying problem is lack of coal, only increasing coal supply can give relief to the market, and this requires the ramping up of coal production and/or improvement in logistics.

With another 50 GW of coal capacity under construction (mainly supercritical and ultra-supercritical), overcapacity is not going to solve itself in the coming years, and it will have implications for the profitability of existing plants. New, modern, efficient, low-emission, flexible coal plants are best positioned for being used in the future. By contrast, old inefficient plants, which require expensive retrofits to comply with environmental standards, are in a difficult position. The GoI is identifying the plants that can and will need to run more flexibly in the system and is looking at market design reforms to improve the remuneration of the system services they can provide.

India continues its efforts to foster efficiency and ensure the implementation of emissions performance standards aimed at reducing air pollutants and emissions from coal power plants. For example, the Perform, Achieve and Trade (PAT) scheme supports energy efficiency upgrades through the market-based trading programme for efficiency certificates under National Mission for Enhanced Energy Efficiency (NMEEE), one of the eight missions of National Action Plan on Climate Change (NAPCC).

While the IEA acknowledges the efforts made by the GoI to promote stringent standards and efficiency programmes, pollution control remains a burning issue. A total of 170 old thermal generation units with a cumulative capacity of 10.64 GW had been retired by March 2018. The most acute air pollution problems are caused by the oldest plants with a total capacity of around 23 GW, which have already exceeded their design life, are working at low load factors, and are both inefficient and polluting. Unless supported by subsidies or tariff increases, any investment to improve efficiency or reduce emissions is difficult to recover. Provided that energy security is not compromised, those coal plants should be closed down. Real progress on the ground has been very limited since the 2017 deadline for compliance was pushed to 2021/22. As much as 23 GW of old, inefficient subcritical power plants could be retired by 2022 (2021 for certain plants) and the government should ensure this will be implemented for the plants that cannot be retrofitted. A two-year compliance period was too short compared to other jurisdictions, where it took on the average 10-20 years.

International experience (in Japan, Europe, North America and China) suggests it is possible to reduce emissions from coal power plants dramatically based on a mix of "sticks and carrots", i.e. regulation with some incentives for compliance combined with a long transitional period to avoid energy security issues. In 2019 the government has announced it is to allocate public subsidies to assist with compliance (as international finance is not available for coal-fired power plants and electricity price increases are difficult to implement). GoI is now focusing on the implementation of the current NO_X standards and is no longer pursuing the tightening of the standards after 2022, following the Supreme Court ruling of August 2019. With proper maintenance and refurbishment or upgrades, the units could be operated in a satisfactory manner with significant benefits from reduced air pollution.

The greenhouse gas emission footprint of coal-fired power generation could be reduced by carbon capture, utilisation, and storage (CCUS). India has created a programme for CCS and is interested in promoting it through Mission Innovation. Several oil and gas companies, including ONGC, are investigating the potential for CO_2-based enhanced oil recovery and NTPC is interested in CCS. However, a stronger push is needed to promote the development of CCUS and an embryonic CCUS industry. To pursue this, India will need to conduct an appraisal of suitable storage sites, which could be started drawing on international expertise, to fully understand the potential for CCUS.

Recommendations

The Government of India should:

- Improve the design of the auctions for new commercial coal mines and ensure a one-stop-shop for permitting of new mines.
- Ensure that coal allocation and pricing formulas incentivise companies to direct coal to its most efficient use.
- Further improve railway logistics for coal supply, for example by allowing dedicated lines to be built in areas where future mining capacity will increase and by reducing cross-subsidy.
- Focus on rapidly retrofitting and upgrading the current coal generation fleet to:
  - continue to improve coal power generation efficiency through low-cost measures, including wider adoption of best practices, which will reduce coal consumption and emissions both of pollutants and CO_2
  - support investment in the flexibilisation of coal plants with new state-of-the art technologies
  - continue to reduce air pollution from coal power generation by fostering compliance with enacted emission standards and closing down the oldest plants, if they cannot be refurbished, in line with National Electricity Plan proposals to close 22.7 GW by 2022.
- Assess the wider potential role of CCUS in India, including a thorough survey of CO_2 storage potential.

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10. Oil

Key IEA data

(2017*)

Crude oil production (2018): 840.1 kb/d, up 3% since 2008

Oil refinery outputs (2018): 5.4 mb/d, up 45% since 2012

Total oil net imports (2017): 3.4 mb/d, up 54% since 2007 (crude oil net imports: 4.3 mb/d; oil product net exports:1.0 mb/d)

Share of oil (2017): 25% of TPES and 32% of TFC

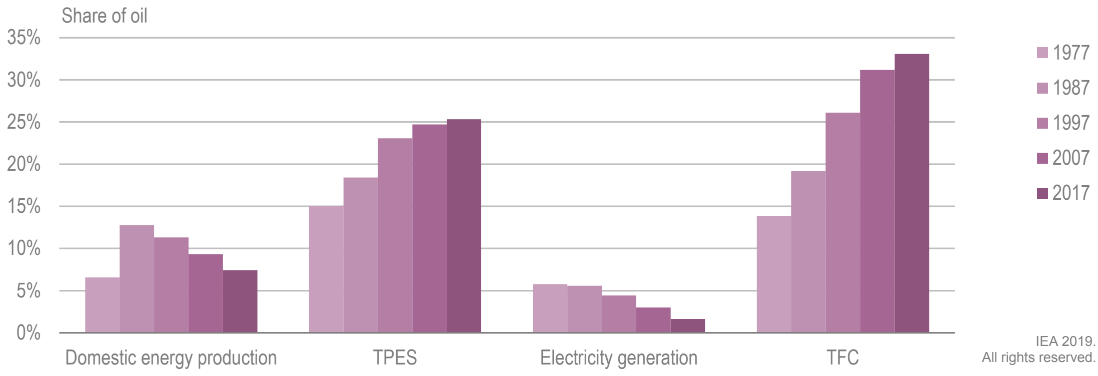
Consumption by sector (2017): 4.4 mb/d (transport 41%, buildings 19%, industry 12%, petrochemical feedstock 9%, agriculture 5%, power generation 4%, others 12%)

* India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. So, the statement: "In 2017 consumption was 937 Mt" refers to the data India has collected (and supplied to the IEA) from 1 April 2017 to 31 March 2018.

Overview

Oil remains an essential energy source for India. It is the second-largest source in the country's total primary energy supply (TPES) and the largest in its total final consumption (TFC). Oil demand has increased rapidly over the last several decades and India is now the third-largest oil-consuming country in the world.

Figure 10.1 Share of oil in the energy system, 1977-2017



The role of oil in India's TPES and TFC has steadily increased for decades, but has shown signs of stabilising in recent years.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

In the last decade, India's domestic oil production has remained relatively stable at an average of 862 thousand barrels per day (kb/d), with an annual average growth rate of 0.3%, but oil's share of total domestic energy production has declined (Figure 10.1). For refined products, India's production has increased steadily and the country is currently a net exporter.

Over the same period, India's oil demand grew by more than 50%, mostly led by rapid growth in gasoline and diesel for transport, the largest oil-consuming sector, and liquefied petroleum gas (LPG) in cooking. While the rate varies, oil demand has been growing across all sectors and is expected to surpass that of the People's Republic of China ("China") in the mid-2020s as India becomes the leader of oil demand growth.

With continued strong growth in oil demand against falling domestic production, India has become more reliant on oil imports, which hovered around 83% in 2018. At the same time, India's import bill for crude oil has increased by 27% from USD 88 billion in 2017 to USD 112 billion in 2018.[1] In March 2015 Prime Minister Modi set out a roadmap to reduce India's oil imports by 10% by 2022. To address this, India has been broadening its strategic partnerships through international bilateral investment and foreign direct investment in India to diversify the country's import sources and suppliers. The Government of India (GoI) has created the Indian Strategic Petroleum Reserves (ISPRL) to build its strategic crude oil reserves. With net imports expected to grow in the future, India can benefit from further reinforcing its oil emergency response policy, with increased emergency stocks and demand-restraint measures to counterbalance disruptions. As oil demand is expected to remain robust, India should also continue to enhance its international engagement in oil security issues.

Supply and demand

Oil supply

In 2018 India's domestic oil production stood at 840 kb/d, which is 3% up from a decade ago, but 8% down from its peak of 910 kb/d in 2011 (Figure 10.2).

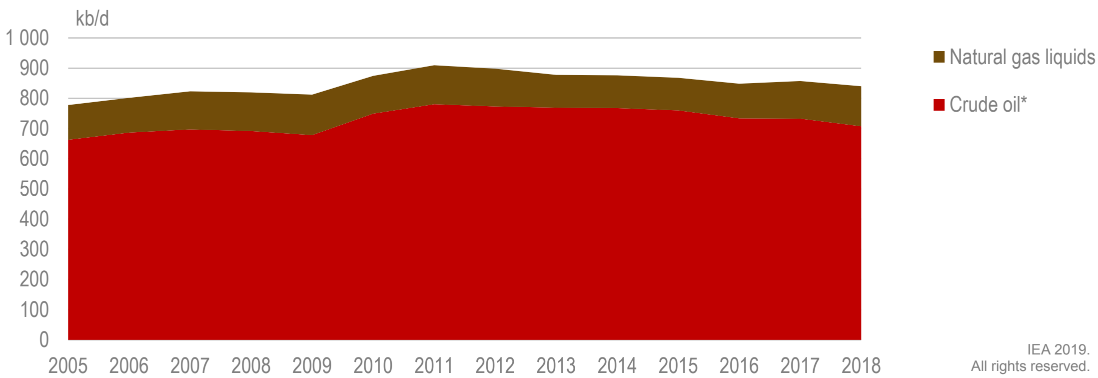
The estimated total volume of India's conventional hydrocarbon resources from 26 sedimentary basins is estimated to be around 47.8 billion tonnes of oil equivalent.[2] According to the 2017/18 Indian Petroleum and Natural Gas Statistics report, India's proven reserves of crude oil and condensate as of April 2018 were around 595 Mt (around 4.4 billion barrels), which could potentially sustain production for about 14 years at current levels (MoPNG, 2018a).

Location-wise, oil production in India comes primarily from three onshore states, Assam, Gujarat and Rajasthan, which together account for more than 96% of onshore outputs, and from the aged offshore Mumbai High Field. Some recent discoveries in Rajasthan and in the offshore Krishna-Godavari (KG) basin hold some potential.

[1] Petroleum Planning and Analysis Cell (PPAC) assumes an Indian basket crude oil price of USD 57.77 per barrel and a USD/INR exchange rate of 70.73.

[2] The estimate was defined by a multi-organisation team of GoI and representatives of Oil and Natural Gas Corporation (ONGC), Oil India Limited (OIL) and the Directorate General of Hydrocarbons (DGH).

Figure 10.2 Domestic oil production, 2008-18



India's crude oil production has remained relatively stable during the past decade.

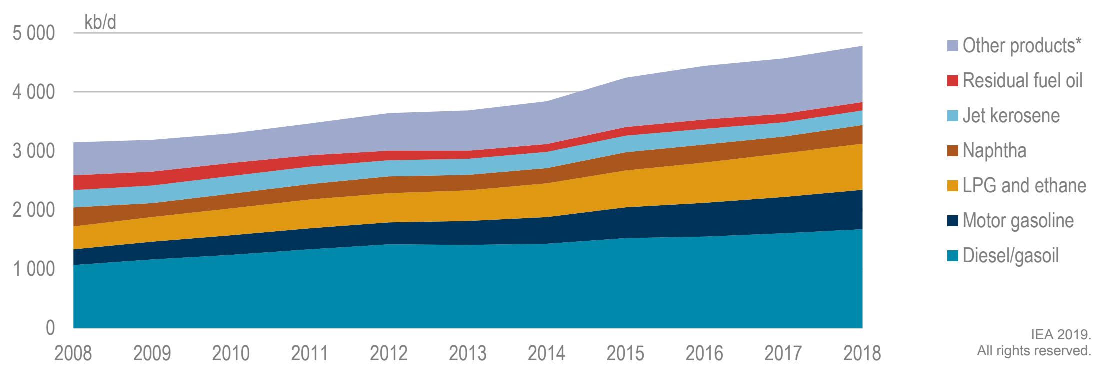
**Crude oil* includes condensates.

Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

India's crude oil production is expected to show only a marginal increase in the medium term, 2019-24 (IEA, 2019c). Growth is expected to primarily come from ONGC's KG-DWN-98/2 deep water oil and gas development, with output starting in 2020 and reaching 78 kb/d of oil at peak production.

Since 2012 India's production of petroleum products has increased by around 17% to reach 7 998 kb/d in 2018. Diesel oil is the largest product, accounting for around 40% of the total petroleum production, followed by gasoline at 15% (Figure 10.3).

Figure 10.3 Refinery outputs, 2012-18



Diesel dominates domestic oil refining outputs, followed by gasoline.

**Other products* include crude oil, "other" natural gas liquids, synthetic fuels, Orimulsion, hydrogen, synthetic crude, refinery gas, aviation gasoline, naphtha-type jet fuel, white spirit, industrial spirit (SBP), lubricants, bitumen, paraffin waxes, petroleum coke, tar, sulphur, aromatics and olefins.

Note: Refinery outputs of the individual products do not include LPG produced outside of the refinery from other sources (e.g. natural gas liquids).

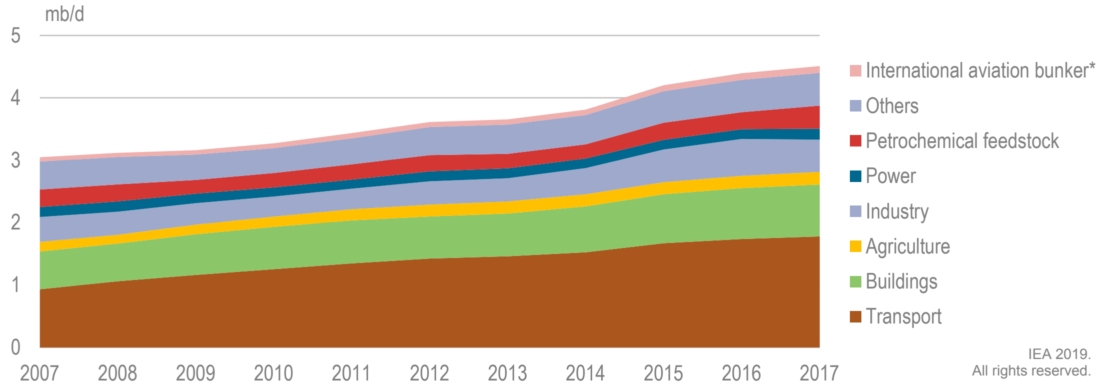
Source: IEA (2019b), *Oil Information 2019*, https://www.iea.org/statistics/; IEA (2019d), *Monthly Oil Data Service 2019*, https://www.iea.org/statistics/mods/.

The International Energy Agency (IEA) estimates Indian refining capacity to increase by 0.5 mb/d in the medium term to 2024 (IEA, 2019c) to reach 5.7 mb/d. This amounts to only half the expected oil product demand, hence net exports of diesel are expected to decrease in the medium term. Refining capacity remains a constraint until the 1.2 mb/d Ratnagiri mega-refinery comes online.

Oil demand

Driven by rapid economic growth, oil demand in India has been growing for decades across all sectors. India's oil demand has risen strongly since 2008, with average demand growth close to 160 kb/d per year to reach 4.4 mb/d in 2017, which already represents 5% of global consumption. India's oil demand is expected to reach around 6 mb/d by 2024, representing 3.9% growth per annum, well ahead of the global average of 1.2%. The country is set to overtake China in the mid-2020s as the largest source of global oil demand.

Figure 10.4 Oil consumption by sector, 2007-17



Oil demand for transport, the largest oil-consuming sector in India, has almost doubled in the past decade.

*International aviation bunker is excluded from total oil consumption.

Note. *Buildings* include residential and commercial; *Others* include energy own use, non-energy use such as bitumen and asphalt, district losses and statistical difference.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Transport

The transport sector, largely road transport fuelled by diesel and gasoline, is not only the largest oil-consuming sector in India, accounting for 41% of total consumption in 2017, but also the fastest-growing (Figure 10.4). Over the past decade, oil use in transport has increased by 91%. The buildings sector, including both residential and commercial, accounted for 19% of total oil demand. In the residential sector, LPG accounts for a dominant share at around four-fifths of demand, mostly for used cooking, and kerosene for the remaining one-fifth, for heating. Industry is the third-largest oil-consuming sector at 12% of total demand, followed by the booming petrochemical sector at 9%.

India's rapid growth in oil consumption is mainly driven by the transport sector. India has one of the world's fastest-growing passenger car markets. The number of passenger vehicles per 1 000 people was 26 in 2017, far behind the Organisation for Economic Co-operation and Development average of 442, and less than half the Association of Southeast Asian Nations average of 56 (IEA, 2017).

India builds 40 kilometres of highways per day and is forecast to have eight times more passenger cars and four times more commercial vehicles by 2040 compared with 2017.

Global oil demand for trucking is expect to increase by 4 mb/d up to 2040, and India's share of this increase is put at 40%, indicating the country's steady growth in freight activities (IEA, 2018c). India's demand for diesel, also used for rail transport, rose by 70 kb/d in 2018 and is expected to continue rising by 75 kb/d in 2019. Albeit still a small share, India's jet fuel demand is also escalating to fuel the world's fastest-growing aviation market. With a combination of rising incomes, increased airport connectivity and falling air fares thanks to low-cost air carriers, India's number of passengers rose to over 160 million in 2018 from only 50 million a decade ago. The GoI is also keen to enhance the country's aviation infrastructure to encourage connections to smaller cities. India's jet fuel demand is expected to rise by 8.2% per year between 2018 and 2024 (IEA, 2019c).

Another interesting development in India's transport sector is biofuel. With an objective to reach 20% ethanol blend in gasoline and 5% biodiesel blend by 2030, the GoI introduced a new National Policy on Biofuels in 2018. This includes a new Ethanol Blending Programme that extends the scope of second-generation ethanol procurement to include oversupply of food grains such as maize and fruit/vegetable wastes. Previously, only excessive supply of sugarcane was allowed to be converted into ethanol, which restrained the feedstock availability to meet the blending target. The GoI foresees that an increase in alternative fuels in the transport sector would help reduce the dependence on crude oil imports and promote low-carbon transition in transport.

Petrochemical industry

Petrochemicals play an essential role in enabling the key sectors of the economy to grow. In line with the anticipated 257% growth in India's plastic consumption between 2017 and 2050, the country's petrochemical capacity[3] is expected to further increase from its current level of 16 Mt per year, which accounted for 4% of the global capacity in 2017 (IEA, 2018a).

The "Make in India" programme will give a boost to the country's manufacturing industry, such as the automotive sector, requiring more plastics, and the increased focus on agriculture and irrigation will accelerate the demand for petrochemical fertilisers. The GoI's thrust to improve national infrastructure will also stimulate the demand for synthetic materials for construction.

In order to meet such growing demand for petrochemical products, a number of Indian state-owned energy companies are making major investments to further promote their petrochemical activities, and are expected to become significant players in the sector. Capacity expansions by several other manufacturers are moving ahead and gradually filling the gap between domestic demand and supply. Overall, the outlook for the petrochemical industry in India is more positive than it has been recently, as the growth in gross domestic product (GDP) and industrial outputs in key end-use sectors (such as automotive and packaging) are expected to be higher than in previous years.

Residential: Clean cooking

The GoI has been promoting LPG as a clean and easy cooking fuel across the country, particularly for rural areas, which made India one of the world's largest LPG consumers after China. LPG is playing a significant role in addressing Indian households' prevalent usage of traditional fuels such as firewood and cow dung, which have proven to be

[3] High-value chemicals (HVC) capacity. HVCs include ethylene, propylene and BTX (benzene, toluene and mixed xylenes).

hazardous for both health and the environment, and a hindrance to the economic development of women.

LPG is heavily subsidised in India, which has been a fiscal burden on the government (see section on retail market and prices). To ensure that the subsidies are provided to the right recipients who need fiscal support, the GoI introduced three significant initiatives, the Direct Benefit Transfer in 2013, the Pradhan Mantri Ujjwala Yojana (PMUY) programme for women, and an initiative to encourage wealthier households to give up their subsidies (#GiveItUp).

In 2013 the Direct Benefit Transfer approach to distributing the LPG subsidy was introduced to ensure the direct transfer of the subsidy into Aadhaar-linked bank accounts approved by the GoI, thereby reducing payment leakage and distortions (for instance, use in the commercial sector). Modern IT technology (JAM) is used to allocate the subsidies through electronic bank accounts, Aadhaar digital ID cards (direct transfer), and mobile phones, along with integrated national databases. Social media is used to spread information and promote the LPG programmes besides trainings.

Launched in May 2016, PMUY aimed to provide deposit-free LPG connections to 50 million women from the below poverty line households over a period of three years. The 2018 budget increased the ambition to provide LPG connections to 80 million households by 2020. India had already achieved this target by the end of August 2019.

Another commendable initiative is the #GiveItUp campaign, set up as a part of LPG subsidy management in 2015. The campaign encourages consumers who can afford the market price for LPG to voluntarily give up their subsidies. By February 2019 almost 10 million LPG consumers had voluntarily surrendered their subsidies to the government budget, which were redistributed to low-income families (MoPNG, 2019). Through the Direct Benefit Transfer, PMUY and PAHAL, the budget has saved around USD 2 billion per year, with total accumulated savings expected to be around USD 9 billion during 2014-20.

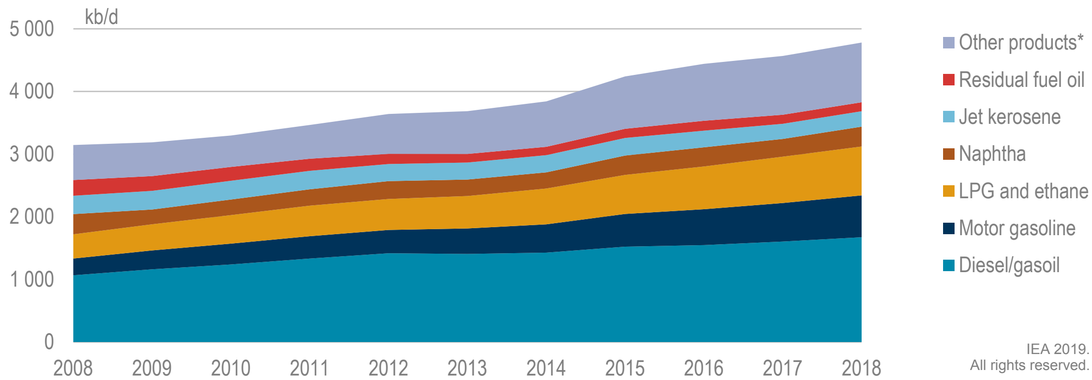
The oil marketing companies and some state governments provide subsidies for gas stoves and the first fill when households purchase LPG bottles. All LPG consumers buy the fuel at market price. The Goods and Services Tax (GST) on LPG is calculated at the market rate of the fuel. Indian Oil, Bharat Petroleum and Hindustan Petroleum are the main oil companies implementing the LPG schemes through more than 23 000 distributors. Oil companies have expanded the LPG pipeline network, supported by new import terminals and several large new bottling plants. Oil firms revise the LPG price on 1st of every month. As of 1 March 2019, the 14.2 kg subsidised LPG cylinder cost INR 495.61 and the non-subsidised or market-priced LPG cylinder cost INR 701.50 in Delhi. The subsidy transfer increased to INR 205.89 per cylinder in March 2019, against INR 165.47 in February 2019.

Diesel is the largest oil product consumed in India – it accounted for 35% of the total in 2018 (Figure 10.5). While gasoline's share (14%) remains far below that of diesel, it has experienced the highest average growth rate of 10% over the past decade, compared to 5% average growth rate for diesel consumption.

LPG, mostly used for cooking, is the second-largest oil product consumed in India and had an average growth rate of 7% over the same period. In 2019 India became the second-largest consumer of LPG after China, with supplies coming from Saudi Arabia and the United Arab Emirates.

Others, including naphtha, jet kerosene and residual fuel oil, all have flat or declining growth rates at 1%, -2% and -5% respectively in 2008-18.

Figure 10.5 Oil demand by product, 2008-18



Transport fuels remain the primary oil products consumed in India, with a rapid demand growth for LPG and ethane.

**Other products* include crude oil, "other" natural gas liquids, synthetic fuels, Orimulsion, hydrogen, synthetic crude, refinery gas, aviation gasoline, naphtha-type jet fuel, white spirit, industrial spirit (SBP), lubricants, bitumen, paraffin waxes, petroleum coke, tar, sulphur, aromatics and olefins.

Sources: IEA (2019b), *Oil Information 2019*, https://www.iea.org/statistics/; IEA (2019d), *Monthly Oil Data Service*, https://www.iea.org/statistics/mods/.

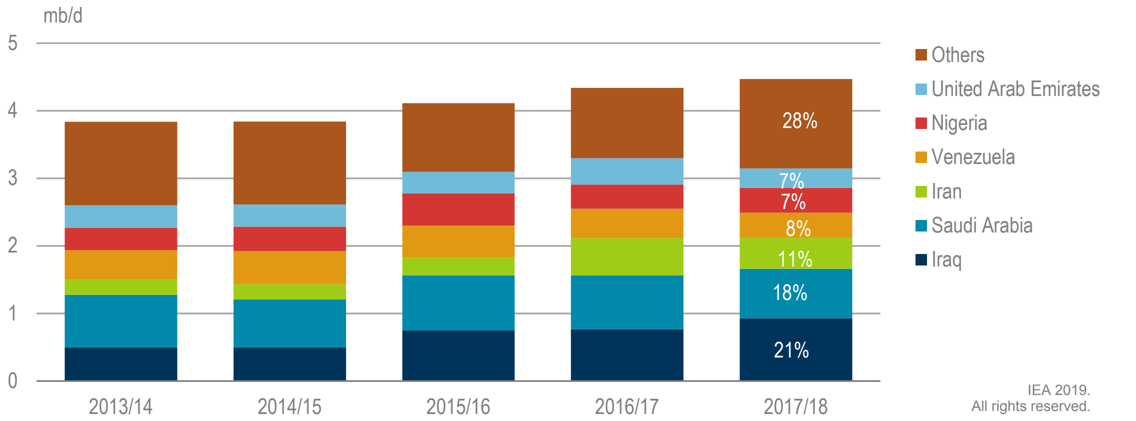
Oil trade: imports and exports

Crude oil imports

India relies heavily on crude oil imports, as domestic production is not sufficient to meet the country's soaring refinery activity and end-used demand. Over the past decade, India's crude oil net imports have increased by almost 90% to 4.3 mb/d in 2017 (DGCIS, 2018). The top three suppliers were all from the Middle East: Iraq (970 kb/d, 21%), Saudi Arabia (800 kb/d, 18%), and Iran (521 kb/d, 11%) (Figure 10.6).

Iraq has replaced Saudi Arabia as India's top crude oil supplier since 2017. In total, approximately 62% of India's imported crude oil came from the Middle East, passing through the Strait of Hormuz. The rest came from Africa (15%), South America (10%) and others. As part of India's efforts to diversify its crude oil sources, Indian Oil Corporation Limited (IOCL) signed a contract with the United States to import 3 Mt (around 61 kb/d) of US crude oil in 2019. Worth USD 1.5 billion, this is the first term contract finalised by an Indian public-sector undertaking (PSU).

Figure 10.6 Crude oil imports by country, 2013-17



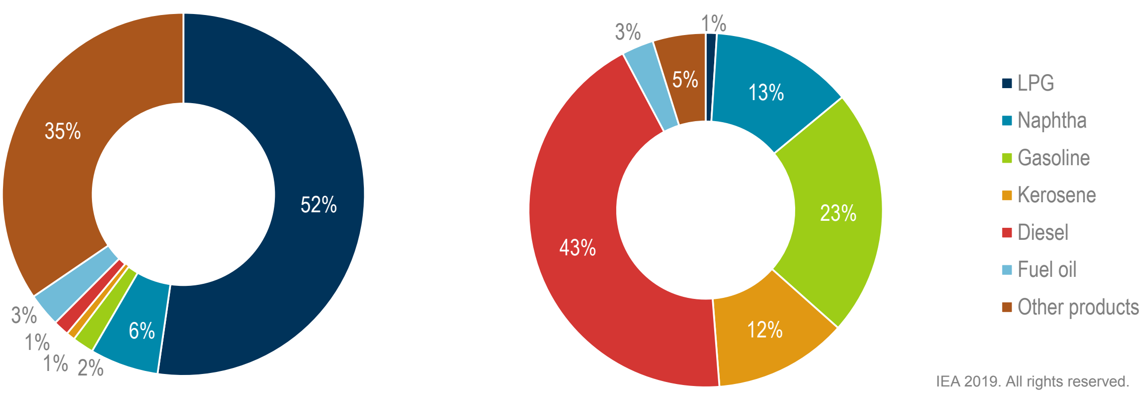
Crude oil imports have increased rapidly to meet demand growth.

Source: DGCIS (2018), *Annual Report* 2017-18, http://www.dgciskol.gov.in/Writereaddata/Downloads/Annual_Report_2017-2018.pdf

Oil products imports and exports

Despite being a net importer of crude oil, India is a net exporter of refined oil products thanks to its large refining capacity. India produces significantly more diesel and gasoline than needed for domestic consumption, which contributes to its exports of oil products (Figure 10.7). Most of the exported oil products in 2018 (1 306 kb/d) were road transport fuels: 43% diesel and 23% gasoline. The top five countries that imported India's petroleum products were the United Arab Emirates, Singapore, the Netherlands, China and Turkey.

Figure 10.7 Imports (left) and exports (right) by share of refined oil products, 2018



Sources: IEA (2019b), *Oil Information 2019*, https://www.iea.org/statistics/; IEA (2019d), *Monthly Oil Data Service*, https://www.iea.org/statistics/mods/.

However, India is still import-dependent on certain petroleum products. In 2018 India imported 800 kb/d of oil products, primarily petroleum coke (part of other products below) and LPG. India stands as world's second-largest importer of LPG after China. The country's LPG imports have markedly increased over the last five years, surpassing the import volumes of Japan. According to state-owned IOCL, 50% of India's LPG demand will be met by imports until 2040 (IOCL, 2018). The increased use of LPG as a cleaner cooking fuel, replacing firewood and kerosene, is expected to turn India into the world's largest LPG importer by 2040 (IEA, 2018c).

India also imports naphtha, for techno-commercial reasons rather than due to a domestic demand–supply gap.

Institutions

The Ministry of Petroleum and Natural Gas (MoPNG) regulates the entire value chain of the oil sector, including exploration and production, refining, distribution and marketing, import and export, and conservation of petroleum products. Under the MoPNG, the Directorate General of Hydrocarbons (DGH) regulates the upstream side of the oil sector, as well as coalbed methane projects.

The Petroleum and Natural Gas Regulatory Board (PNGRB) was created in 2006 to protect the interests of consumers and entities engaged in the sector and to promote competitive markets. PNGRB is also mandated to regulate the refining, processing, storage, transport, distribution, marketing and sale of petroleum, petroleum products and natural gas, excluding production of crude oil and natural gas, so as to ensure uninterrupted and adequate supply in all parts of the country. The PNGRB Act (2006) provides for the promotion of competition in the oil and gas sectors by ensuring the non-discriminatory open access of oil and gas pipeline infrastructure on a common carrier/contract carrier principle at regulated tariffs determined by PNGRB under its notified regulatory framework.

In India, two state-owned companies dominate **oil production and refining** activities. In 2017 the ONGC accounted for 62.3% of total crude production and Oil India Limited (OIL) accounted for 9.5%, with the rest 28.2% from production-sharing contracts.

Retail market and prices

Market structure

India's retail oil market is largely dominated by the state-owned refining and marketing companies Indian Oil, Hindustan Petroleum and Bharat Petroleum, who own around 90% of India's fuel stations (63 000). Reliance, India's largest private refiner and petrochemicals producer, is a small player in the oil retail market (1 400 fuel stations across India).

To obtain a retail licence to sell petrol, diesel and jet fuel in India a foreign player is obligated to make a minimum investment in India's oil production, refining or distribution. In August 2019 the GoI indicated plans to abolish this obligation to further liberalise the market.

To date, only one foreign company has a presence in India's retail market (Shell, with around 100 stations in 2018). India's growing domestic oil market is attracting foreign players. In 2019 Saudi Aramco acquired a 20% stake in Reliance's refining and petrochemicals business. BP signed a joint venture with Reliance (49% stake) to expand Reliance's network to 5 500 stations in the next five years and sell jet fuel at 30 Indian airports. In 2018 Total entered into a partnership with India's private Adani group and plans an investment in 1 500 petrol stations in the country over the next ten years. BP has made investments in India's gas exploration and production business, and secured a licence in 2016 to set up 3 500 retail fuel outlets.

Pricing

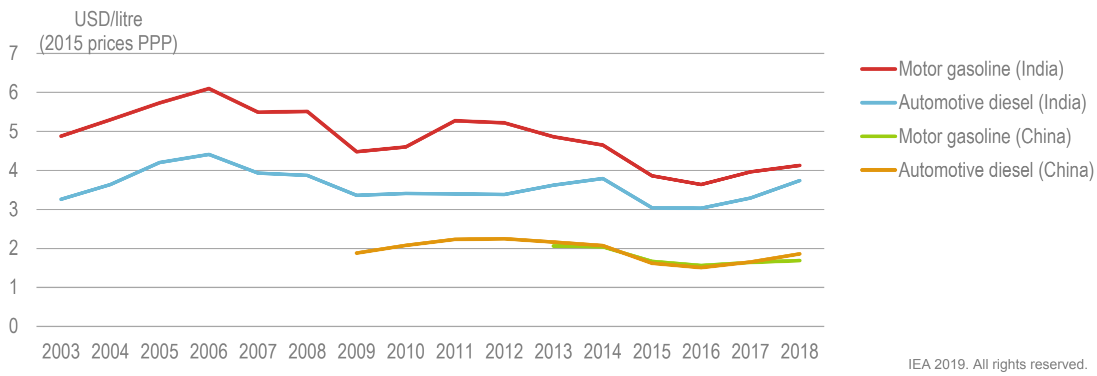
From the 1970s to 2002, the Administered Price Mechanism (APM) was used to control the pricing of petroleum products at four stages: production, refining, distribution and marketing. The purpose of APM was to compensate the related companies for normative costs set by the government and to ensure a return on the oil companies' investments. However, with an upward swing in oil prices in 1980s, the need to deregulate the market grew and the new Industrial Policy in 1991 opened up India's refinery sector to private competition. APM was abolished in April 2002 and the state-owned oil marketing companies (OMCs) were allowed to set retail product prices. While this liberalisation of India's retail sectors resulted in the emergence of small private-sector players, the government maintained its heavy subsidies on LPG and kerosene due to its importance in India's domestic economy as an energy source for low-income households.

In 2004 the GoI reintroduced price controls over four "sensitive" petroleum products: petrol, diesel, LPG and kerosene. In order to insulate domestic consumers from the price volatility of essential fuels, the government regulated the OMCs to make sales at centrally determined prices. As compensation for the OMCs' losses, the government provided grants to them on top of fiscal subsidies, which resulted in added pressure on the GoI budget in times of high global oil prices, such as in 2008.

Eventually, prices for petrol and diesel were deregulated in 2010 and 2014 respectively. Since then, the OMCs have been setting the price of petrol and diesel in line with international prices and other market conditions.

The tax components levied on petrol and diesel include excise duty, imposed by the central government, value-added tax (VAT) and dealer commission, imposed by the state oil companies. Compared with other major developing energy markets, such as China, India has significantly higher fuel prices (Figure 10.8). India's retail fuel pricing mechanism provides lower taxes for products sourced from domestic refineries.

Figure 10.8 Gasoline and diesel prices in India and China, 2003-18



Fuel prices have declined over the last decade, but are significantly above those of China.

Note: Prices for China not available before 2009 for gasoline and 2013 for diesel.

Source: IEA (2019e), *World Energy Prices 2019*, www.iea.org/statistics/.

Upstream: Exploration and production policies

To address production declines from mature basins, the GoI has taken several measures to enhance exploration and production (E&P) of oil and gas in the country:

- **Hydrocarbon Exploration and Licensing Policy (HELP)**: Approved in March 2016 and implemented since July 2017, the HELP replaced the previous licensing policy, the New Exploration Licensing Policy (NELP), which was criticised for its narrow scope and long, burdensome procedures. The HELP unifies the permitting authority into a single register to grant licences for E&P and covers both conventional and non-conventional oil and gas resources. It also introduced pricing and marketing freedom.
- **Open Acreage Licensing Policy (OALP)**: The HELP introduced the OALP in 2017 to further encourage companies to seek permission for exploration of any block at any time by submitting an expression of interest. Previously, there were formal bidding rounds led by the GoI and E&P activities were limited to blocks approved by it.
  - The first round of the OALP was concluded in May 2018, with 76% of the total blocks awarded to private companies; 55 contracts were signed with 6 companies, of which two were private – Vedanta and HOEC – winning 41 contracts and 1 contract respectively.
  - The second and third rounds of the OALP were concluded in July 2019. Contracts were signed for 32 blocks with 6 companies, of which 3 were private companies. Vedanta and BP–RIL won 10 contracts and 1 contract respectively.
  - Under the OALP I, II and III, a total of 87 blocks covering an area of 118 280 km^2 have been awarded so far; 61% of the blocks, equivalent to 51% of the awarded area, were won by private companies, mainly Vedanta (51 blocks), HOEC (1 block) and BP–RIL (1 block).
- **National Data Repository:** In support of the OALP, the government launched the National Data Repository in June 2017. It is a comprehensive archive of geo-scientific data for E&P activities. By allowing companies to access the data through an e-platform and consult relevant information, the government helped the interested parties in making bidding decisions.
- **Discovered Small Field Policy:** Launched in 2016 with an objective to tap unmonetised small oil/gas discoveries in India, Discovered Small Field provides an easy and low-risk investment option for interested parties to encourage E&P activities. Bid round 1 was completed in a record time of 10 months, with 134 bidders for 34 blocks on offer; 30 contracts were awarded to 20 companies, of which 13 were new players in the E&P sector. First oil/gas is expected in 2019/20. In August 2018, for bid round 2 the GoI offered larger areas in commercially producing basins (MoPNG, 2018). A total of 40 companies participated: 29 private, 6 foreign and 5 central public-sector enterprises. In the end, 23 contracts were awarded, of which 15 were to private companies.
- **Enhanced recovery and unconventional hydrocarbons** are supported by the government's policy incentives, including systemic assessment of domestic fields with enhanced recovery potential, evaluation of enhanced recovery techniques, and fiscal incentives to alleviate the risk factors and costs associated with enhanced recovery projects.

The HELP marked an important transition from regulation to liberalisation of India's E&P sector; it is a very significant upstream reform of the fiscal regime. Despite this positive progress, India's growing oil demand is unlikely to be met by new production alone given the country's limited resource base.

Box 10.1 New policy measures to promote oil and gas E&P activities, 2019

On 28 February 2019 the GoI announced a new set of policy measures to boost oil and gas E&P activities in India. Key aspects of the measures include the following:

- The timeline for completion of committed Minimum Work Programme has been reduced.
- No production or revenue sharing, only statutory levies need to be paid except in the case of a windfall gain.
- In the case of windfall gains of more than USD 2.5 billion, revenue sharing varies from 10% to 50% with a ceiling of 50%.
- Full marketing and pricing freedom is granted on an arm's length basis according to competitive bidding.
- To expedite production, concessionary royalties are offered if production commences within four to five years.
- New gas discoveries are given pricing and marketing freedom.
- A series of measures include the streamline the functioning of DGH, such as redefining its role, single-window clearance, standardisation of guidelines and data management accessibility.
- National oil companies are given freedom to choose a field-specific implementation model, such as the Technical Services Model, Joint Venture Model, Farming-out Model, to enhance production.
- National oil companies are mandated to bid-out fields with complete marketing and pricing freedom on a revenue-sharing model under the supervision of DGH.

The GoI has been encouraging companies to acquire foreign upstream assets to reduce its dependence on oil imports. In 2015 ONGC purchased a 15% stake in Vancor, the Russian Federation's ("Russia") second-largest oil field. In 2017 ONGC's indirect subsidiary OVL acquired a 15% stake in Namibia's oil block. In February 2018 an Indian consortium led by ONGC was awarded a 10% stake in Abu Dhabi National Oil Company (ADNOC)'s 40-year offshore concession in Lower Zakum. IOCL also acquired a 17% stake in Oman's oil field in April 2018.

Infrastructure

Refineries

In 2019 India had 23 refineries with a combined refining capacity of around 5.2 mb/d. The proportion of capacity belonging to public-sector, private-sector, and joint-venture refineries stood at 57%, 36% and 7%, respectively. Refinery throughput in 2018 was around 5.1 mb/d and the capacity utilisation rate reached 99%. India's refining industry is one of the most efficient in the world.

IOCL owns 9 refineries and has the largest (28%) share of total refining capacity in India. The three largest single refineries are privately owned by Reliance and Nayara Energy, which add up to a total capacity of 88.2 Mt/y (Table 10.1). They are all located on the west coast of the country facing one of the world's largest crude oil-producing regions – the Middle East – in order to benefit from low transport costs.

Although several refinery projects have faced delays in the past few years due to financial issues or extreme weather events, the world's largest oil refinery and petrochemical mega-project with a capacity of 1.2 mb/d is being planned in Ratnagiri. It is a joint venture of state owned companies – IOCL, Bharat Petroleum and Hindustan Petroleum are taking a 50% stake, with international partners Saudi Aramco and ADNOC. The project was expected to be completed in 2024 and commissioned in 2025, but is running into delays. The completion of this mega-project would boost India's oil product exports after a medium-term slowdown (IEA, 2019a).

Some refineries are planning to upgrade their capacity to produce higher-quality fuels with reduced sulphur, conforming to Bharat Stage (BS) VI (EURO VI) emission standards. Since April 2017 India has been rolling out EURO IV compliant fuels called BS-IV, but has decided to leapfrog the EURO V norms and directly adopt the EURO VI standard from April 2020. In October 2018 the Supreme Court ordered that vehicles only complying with the BS IV fuel standard cannot be sold or registered in the country after 1 April 2020. The development of cities in India is accelerating. An escalating level of air pollution pushed the government to impose BS VI fuels in the National Capital Region (NCR) of Delhi in April 2018. Following the new directions issued by the ministry, BS VI has been adopted in 10 districts of NCR and 3 districts/cities outside NCR (Karauli, Dhaulpur and Agra City) since 1 April 2019, and 7 districts/cities of NCR since October 2019.

India is continuously building up its refining capacity to meet the rising domestic demand and maintain its position as Asia's refining hub. To this end, the GoI prepared a roadmap for India's oil sector to meet projected oil demand in 2040. The roadmap is based on a package of measures: first, to improve domestic production of gasoline and diesel by increasing existing brownfield refining capacity by 125 Mt per year, and build new greenfield refineries at Barmer (9 Mt per year) and on the west coast (60 Mt per year). Based on this plan, India's total refining capacity could reach 401 Mt per year by 2025, and 443 Mt per year by 2030 (554 Mt per year if including 25% export capacity addition). The government anticipates that if the plan is realised, the built capacity would be sufficient to meet India's domestic demand up to 2035. Moreover, as India wants to remain Asia's refining hub, the government plans to further build up its refining capacity (including 25% capacity for export) up to 667 Mt per year by 2040.

Table 10.1 Refinery capacity, 2018

Company	Location	Year of commission	Refining capacity (Mt/y)	Refining capacity (kb/d)
Public sector			**148.766**	**3016**
IOCL	Digboi, Assam	1901	0.65	13
IOCL	Gawahati, Assam	1962	1	20
IOCL	Barauni, Bihar	1964	6	122
IOCL	Koyali, Gujarat	1965	13.7	278
IOCL	Bongaigaon, Assam	1974	2.35	48
IOCL	Haldia, West Bengal	1975	7.5	152

Company	Location	Year of commission	Refining capacity (Mt/y)	Refining capacity (kb/d)
IOCL	Mathura, Uttar Pradesh	1982	8	162
IOCL	Panipat, Haryana	1998	15	304
IOCL	Paradeep, Odisha	2016	15	304
Bharat Petroleum Corporation Ltd	Mahul, Mumbai	1955	12	243
Bharat Petroleum Corporation Ltd	Cochin, Kerala	1963	15.5	314
Hindustan Petroleum Corporation Ltd	Mahul, Mumbai	1954	7.5	152
Hindustan Petroleum Corporation Ltd	Visakhapatnam	1957	8.3	168
PLANNED: Hindustan Petroleum Corporation Ltd	Visakhapatnam 2 (modernisation project)	2021	6.7	136
Chennai Petroleum Corporation Ltd	Manali, Madras	1965	10.5	213
Chennai Petroleum Corporation Ltd	Narimanam	1993	1	20
Numaligarh Refinery Ltd	Numaligarh, Assam	1999	3	61
ONGC	Tatipaka, Andhra Pradesh	2001	0.066	1
Mangalore Refinery & Petrochemicals	Mangalore, Karnataka	1996	15	304
Private sector			88.2	1788
Reliance Industries Ltd	Jamnagar, Gujarat	1999	33	669
Reliance Industries Ltd	Jamnagar (SEZ), Gujarat	2008	35.2	714
Nayara Energy *(Former Essar Oil)*	Vadinar, Gujarat	2006	20	405
Joint venture			17.3	351
Bharat Oman Refinery Ltd	Bina, Madhya Pradesh	2011	6	122
HPCL/MITTAL (HMEL)	Bhatinda, Punjab	2012	11.3	229
PLANNED: Ratnagiri Refinery & Petrochemicals Ltd	Ratnagiri, Maharashtra	2025		1200
PLANNED: ONGC/Cairn Energy	Barmer			
PLANNED: Nagarjuna Oil Corporation	Cuddalore		6	
PLANNED: Hindustan Petroleum Rajasthan Refinery Ltd/Rajasthan state	Barmer, Rajasthan			181
Total refinery capacity			**247.566**	**5019**

Source: MoPNG (2018a), *Indian Petroleum and Natural Gas Statistics 2017/18*, http://petroleum.nic.in/sites/default/files/ipngstat_0.pdf

Ports and pipelines

As of 2018 there were 12 major crude oil ports in India, with a total capacity of around 5.5 mb/d. The major crude oil ports are in Vadinar (1.3 mb/d), Jamnagar (1.2 mb/d) and Mumbai (865 kb/d), all located on the west coast. There are also about 12 ports handling finished products around the coast of India. Around 227 Mt (4.6 mb/d) of petroleum products were handled through these ports in 2017 and their share of total traffic at the ports was 33%. India's crude oil pipelines have an estimated combined capacity of 159 Mt per year (3.2 mb/d). As of March 2018 India had 10 406 kilometres (km) of crude oil pipelines, including

488 km of offshore pipeline. IOCL owns the three longest crude oil pipelines, of which two – Mathura and Panipat – serve refineries close to Delhi from the western coast.

India also has an extensive oil product pipeline network with a total length of 16 612 km, including 2 847 km of LPG pipeline. They are owned by seven different companies, although IOCL controls the majority, and most of the pipelines are small in capacity, the largest being 7.95 Mt per year (162 kb/d).

India has six LPG pipelines with an estimated capacity of around 7.77 Mt per year (158 kb/d). To meet the rising LPG demand, India plans to develop more infrastructure for LPG distribution. IOCL is laying an LPG pipeline from the west coast in Gujarat to Gorakhpur in eastern Uttar Pradesh. This pipeline, with an estimated capacity of 3.75 Mt per year (76 kb/d) could become the longest LPG pipeline in the world. IOCL is also building additional import capacity at Paradeep (east), Kochi (south) and Kandla (west) to meet the increasing requirement for LPG imports.

Storage

As of March 2018, under Phase I of the Strategic Petroleum Reserves programme, India's total storage capacity of crude oil and oil products was around 38 Mt (281 million barrels [mb]), including 5.3 Mt (39 mb) of strategic reserve capacity (see Table 10.2). These strategic reserves are estimated to hold approximately 9.2 days of India's crude requirement according to the consumption pattern of 2018/19. The GoI gave in-principle approval in 2018 for Phase II of the Strategic Petroleum Reserves programme, which has a capacity of 6.5 Mt or almost 50 mb.

Storage sites are situated in 20 locations throughout the country, close to major refineries or terminals connected to pipelines. IOCL has a vast crude oil tank farm of 18 tanks with a total capacity of 1 Mt at Vadinar, on the western coast. There are also crude oil storage tank farms at Mundra (0.5 Mt), Viramgam in Gujarat (0.3 Mt) and at Chaksu in Rajasthan (0.2 Mt).

The total volume of stocks from the publicly owned refineries, which have a throughput capacity of around 3 mb/d, are reported to JODI as being 92 mb (except private refineries Reliance SEZ and Nayara). According to July 2019 data, the closing stocks of crude oil were 6.4 Mt and for petroleum and lubricant products 5.54 Mt. This implies that the days of cover provided by publicly owned refineries stood at around 30 days on average. In total, in 2018 India had 64.5 days of estimated commercial reserves of crude oil, petroleum products and gas including both public and private stocks.

Table 10.2 Strategic petroleum reserves

SPR facility	Capacity (Mt)	Capacity (mb)
Vishakhapatnam	1.33	9.6
Mangaluru	1.5	11
Padur	2.5	18.4
Total Phase I	**5.33**	**39**

Security of supply

Emergency response policy and strategic stocks

India officially decided to establish a strategic petroleum reserve in January 2004. In June 2004 the Indian Strategic Petroleum Reserves Limited (ISPRL) was formed as a wholly owned subsidiary of the Oil Industry Development Board (OIDB) under the MoPNG, to implement and manage proposed reserve projects. The entire SPR volumes are expected to be in the form of crude oil.

In 2005 India's Integrated Energy Policy recommended creating emergency oil stocks equivalent to 90 days of oil imports (Planning Commission, 2005). In 2008, the GoI approved the construction of rock caverns as Phase I of India's strategic petroleum reserve scheme, with a total capacity of up to of 5.33 Mt (around 40 mb) in three locations – Vishkhapatnam (1.3 Mt), Mangalore (1.5 Mt), and Padur (2.5 Mt). In 2008 the amount proposed was equivalent to 18 days of net oil imports (2.2 mb/d), but as of 2019 the reserves foreseen under Phase I are estimated to supply approximately 9.2 days of India's crude requirement, according to the consumption pattern of 2018/19. The construction of all three sites was completed by 2018 and currently the caverns are in the process of being filled.

In December 2011 the Secretary of the MoPNG stated that the GoI was planning to significantly expand the stockpile by building additional storage capacity as Phase II of the project. In October 2018, after a detailed feasibility study conducted by ISPRL, the GoI has given in-principle approval for Phase II of the SPR programme. The SPR reserves are proposed for construction with a capacity of 29.2 mb (4 Mt) at Chandikhol in Odisha and 18.25 mb (2.5 Mt) at Padur in Karnataka. The construction and filling of the reserves are being explored under a public–private partnership (PPP) model, with a tender for building the second-phase stocks to be opened by end of 2020. If fully filled, this second phase would add another 11.2 days of net imports, based on the 2018/19 consumption pattern. However, as India's net import volume is expected to more than double by 2040, the number of days covered is likely to further decrease. India envisages international co-operation with IEA countries on global experience on stockholding mechanisms and emergency response, including the United States, for Phase II of its SPR programme (see Box 10.2)

Box 10.2 The IEA oil stockholding mechanisms

In accordance with the International Energy Programme, all IEA member countries are required to hold emergency oil stocks equivalent to at least 90 days of their net imports. This basic oil stockholding obligation of IEA member countries was first formulated in 1974 to establish a "common emergency self-sufficiency in oil supplies". This commitment can be met through stocks held exclusively for emergency purposes and stocks held for commercial or operational use, including stocks held at refineries, port facilities and in tankers in ports.

Stockholding regimes vary among IEA member countries, reflecting differences in oil market structure, geography and national policy choices related to emergency response.

In general, there are three approaches to ensuring that overall stock levels meet minimum requirements: government stocks, agency stocks (where a stockholding arrangement involves the establishment of a separate agency endowed with the responsibility of maintaining all or part of the stock obligation) and obligated industry stocks (placing minimum stockholding obligations on companies in domestic oil markets). Some countries use only one category of these, whereas most countries use a combination of categories to meet the minimum obligation.

The IEA stockholding obligation does not specify whether stocks should be held in the form of crude or refined oil. The most appropriate choice between holding reserves in either crude or oil products depends on factors in each country. Countries with a large refining industry are likely to hold more crude oil, which provides greater flexibility in times of crisis. In countries that have limited domestic refining capacity or rely on product imports to meet a large share of domestic demand, there is a greater tendency to hold reserves of refined products.

Emergency oil stocks are a powerful policy tool for mitigating short-term physical supply disruptions and providing liquidity to allow market recovery. Their use in a disruption provides economic benefits by enabling oil supply to be restored while dampening oil price spikes and avoiding substantial import costs and GDP losses. A 2018 IEA study, *The Costs and Benefits of Emergency Stockholding* (IEA, 2018b) shows the substantial overall benefits of holding emergency oil stocks in comparison to the costs associated with building and maintaining these stocks.

In 2018, together with the known commercial stocks stored at refineries, total oil stocks in India are currently estimated to be around 175 mb, which is equivalent to 46 days (2018 number) of their net imports. They are composed of the crude oil from the strategic reserves (20 mb), commercial stocks at public refineries (91.7 mb [51.7 mb crude and 40 mb products]), and commercial stocks at private refineries (63 mb [estimated by combined refinery capacity of 2.1 mb/d and 30 days' cover, 15 days each for crude and products]).

For the purpose of a joint stockpiling project, India is co-operating with ADNOC to store crude oil at the strategic reserve sites. According to the agreement, the entire amount of oil stored by ADNOC would be made available to India in case of an emergency; but in normal times, ADNOC can trade a part of the crude oil with Indian refineries on a commercial basis, while a mutually agreed minimum crude storage for emergency purposes should be kept. In January 2017 ISPRL and ADNOC signed a contract to store 5.86 mb of ADNOC crude oil at the strategic reserve site in Mangalore. In November 2018 a second joint stockpiling contract was signed with ADNOC to store 9.2 mb of oil at the strategic reserve site in Padur. The GoI created a state-led committee, chaired by the Secretary of the MoPNG, to make decisions on the release and replenishment of oil from strategic reserves.

India does not place an obligation on its industry to hold a certain amount of stocks.

Demand restraint

India does not have any policy to manage the demand for oil during an oil supply emergency, apart from general provisions under the Essential Commodities Act 1995 to maintain equitable distribution of petroleum products.

An Emergency Response Assessment was carried out in collaboration with the IEA in 2013/14, followed by constructive recommendations. PPAC has carried out a vulnerability assessment of the concentration of infrastructure in the selected areas. New infrastructure being constructed since the assessment has been spread out across the east and west coast equally to better respond to emergency disruptions.

Assessment

India is the world's third-largest consumer of oil after China and the United States. The growth of oil consumption in India is expected to surpass that of China in the mid-2020s. Its oil consumption of 4.4 mb/d in 2017 already represents 5% of global consumption, and it is set to grow at a rapid pace of 3.9% per year (well ahead of the global average of 1.2%) in the medium term (IEA 2019c), despite the market penetration of alternative fuels like biofuels and gas. The GoI is pursuing a policy of decreasing the country's import dependence on oil, alongside encouraging increases in renewable energy and natural gas usage.

This rapid growth is mainly driven by transport, mostly freight. Industry is the second main oil consumer, including for non-energy use in the chemical and petrochemical industry. The increased use of LPG as a cleaner cooking fuel, replacing firewood or kerosene, makes India one of the world's largest LPG importers.

Proven oil reserves in India are limited compared to domestic needs and production is in decline. The possible new discoveries in Rajasthan are unlikely to fully compensate for the depletion of existing fields. A new policy framework with fiscal incentives to promote enhanced recovery was issued in October 2018 and February 2019.

India's strong dependence on oil imports, already at 83%, is expected to increase. With an oil import bill of around 4% of GDP today, and 65% of imports coming from the Middle East through the Strait of Hormuz, the Indian economy is and will become even more exposed to risks of supply disruptions, geopolitical uncertainties and the volatility of oil prices.

The operationalisation since 2017 of HELP is a welcome new step to liberalise the upstream market and attract foreign investors. The Round 1 of the OALP was successfully concluded in May 2018, with around 76% of the total blocks being awarded to private companies. It is well recognised that foreign investors can not only contribute to the diversification and security of supply, but also be an effective vehicle to import international good practices on decommissioning and the safety of offshore operations. However, the appetite of foreign investors remains low for now, reflecting how the upstream sector remains highly concentrated in the hands of India's national oil companies, which hold the lion's share of acreage but have financial constraints on developing them, and the poorly documented geological reserve base (Sen A., 2016).

India is improving the quality of its geological data, but there is still a perceived low potential for oil prospects in comparison with other sites in the world.

India is the fourth-largest oil refiner of the world and a net exporter of refined products. According to India's roadmap on oil refining, the country's aims to reach 443 Mt total refining capacity by 2030, exceeding its estimated domestic demand level. In the medium term out to 2025, the IEA expects India to add 0.5 mb/d of refining capacity by 2024 and see reduced diesel net exports due to refinery capacity being below demand growth.

The IEA welcomes the attention given by the GoI to energy security, which in the oil sector is reflected by two main developments. The first is the active energy diplomacy of India to diversify its sources of supply and to acquire shares in overseas oil fields (Russia, Oman, the United Arab Emirates and Namibia). This progress indicates a successful transition from the conventional buyer–seller engagement to a strategic partnership based on bilateral investments. The second is the progressive building up of dedicated oil emergency stocks as part of an internal oil emergency response policy.

India's dedicated oil emergency stocks are in the form of crude oil held by ISPRL to supplement the commercial storage at refineries. The first underground caverns for the strategic reserves with a capacity of 40 mb have been built and are now filled, partly by the stocks owned by ISPRL, and partly through a public–private partnership with ADNOC. A second phase for additional capacity of 50 mb is now under preparation, with new sites selected in October 2018. The business model and the type of public–private partnerships to build the caverns of the second phase are still under investigation. In 2019 Saudi Aramco also voiced interest in investing. The United States has announced support to the efforts of India to increase its strategic oil reserves.

India's net oil imports are expected to more than double up to 2040. Today's ISPRL storage capacity of 40 mb can cover around 10 days of present day net imports. But the same volume will cover only 4 days of net imports in 2040. It is therefore important to indeed pursue the announced second phase of the strategic stockholding policy and prepare future phases. The IEA welcomes current efforts to intensify discussions with potential investors and other countries with a long experience of holding stocks.

The GoI has announced it will drop investment requirements for local content amidst plans for further opening up the oil market. However, the GoI should balance the interest in attracting investment with the need for investment in the security of supply, including stockholding and reserves.

The existing contingency plan should be reviewed to ensure that in the case of a serious supply disruption, the emergency stocks are available and physically accessible for the large consumption centres across the whole territory. The 2012 joint India–IEA Emergency Response Exercise had detected that the infrastructure to connect Delhi was vulnerable. The subsequent emergency response assessment carried out by the IEA in 2013/14 provided constructive recommendations, which were well received by the GoI. The GoI asked PPAC to carry out a vulnerability assessment of the concentration of infrastructure in particular areas. With considerable new infrastructure being constructed since then, the Indian government is open to re-evaluating the adequacy of infrastructure in collaboration with external institutions such as the IEA. The emergency plan could also be expanded to identify priority users and to include demand restraint measures in case of imminent major disruptions.

Internal inter-ministerial procedures at the central government level have also been established to release oil stocks in case of an emergency. However, in case of a serious disruption, the challenge still remains to ensure proper co-ordination between the central government, the states and industry actors. The division of responsibilities between multitudes of actors should therefore be clarified for more efficient co-operative response during a crisis.

Investment is needed to upgrade the capacity of refineries to comply with the new emissions standard BS VI (EURO 6), requiring fuels with reduced sulphur content. There is scope to improve India's oil market framework to increase refinery output sold at market prices and ensure a level playing field between the national oil companies, joint ventures and private companies. The PNGRB was created in 2006 to protect the interests of consumers and entities engaged in the sector and to promote competition. Regulatory oversight is important to ensure non-discriminatory third-party network access, in particular on pricing, over which PNGRB has no legal authority. Therefore, India's regulatory oversight of the sector could be further strengthened to ensure non-discriminatory access and pricing. This becomes even more important given the emerging foreign investment and the many new players entering the Indian oil market.

India should be commended for its reform of LPG subsidies. Action to better target and rationalise LPG subsidies by organising a direct transfer of the aid for cooking gas to the appropriate users has been a tremendous success. The Direct Benefit Transfer and Pratyaksh Hanstantrit Labh (PAHAL) have improved the health of the indoor environment and its occupants, and saved in total USD 8.8 billion during 2013-19. The IEA encourages India to further target subsidies in the oil sector to foster clean energy access for all.

Recommendations

The Government of India should:

- ☐ Reinforce its oil emergency response policy to adapt it to the expected strong growth in oil consumption, with increased dedicated emergency stocks and procedures, including demand restraint measures and a proper analysis of risks by using oil disruption scenarios.
- ☐ Enhance international engagement by India on global oil security issues.
- ☐ Strengthen the regulatory oversight of the sector, non-discriminatory access to oil transport and the level-playing field in the mid- and downstream oil sector.
- ☐ Further promote the diversification of oil sources and reduce India's high oil import dependence by enhancing exploration and production activities and the development of alternative sources, such as biofuels.

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11. Natural gas

Key IEA data

(2017*)

Natural gas production: 31.7 bcm (26.6 Mtoe), up 0.8% since 2007

Imports: 27.4 bcm

Share of natural gas: 5.8% of TPES, 4.6% of electricity generation and 6.1% of TFC

Gas consumption by sector: 59.5 bcm (industry 61.6%, power generation 27.9%, service 2.0%, residential 1.6%, other energy 1.3%)

*India collects data based on its fiscal year, which runs from 1 April to 31 March. To align with other countries, the IEA data on India in this report are presented as calendar years. So, the statement: "In 2017 total gas supply was almost 60 bcm" refers to the data India has collected (and supplied to the IEA) from 1 April 2017 to 31 March 2018.

Overview

India's natural gas consumption is small but increasing. Most gas is used in the industrial sector and in power generation. Residential gas consumption is small, but India is expanding its gas distribution networks rapidly, an area where major growth is expected. Some states and cities also promote gas vehicles to reduce emissions from the transport sector. Domestic production covers just over half of India's gas supply. The rest is imported in the form of liquefied natural gas (LNG), which has increased rapidly in recent years, thanks to the decline in global gas prices. Investment in new LNG terminals is on a rapid rise. In 2014 India linked its domestic gas price to a basket of international LNG prices. Since domestic gas production has developed below expectations, gas use for power generation struggles to compete with cheap coal and renewables under the current contracted import prices. To stimulate more domestic production of oil and gas, the Government of India (GoI) has introduced a Hydrocarbon Exploration and Licensing Policy (HELP), which brought freedom of price setting and marketing for new gas production.

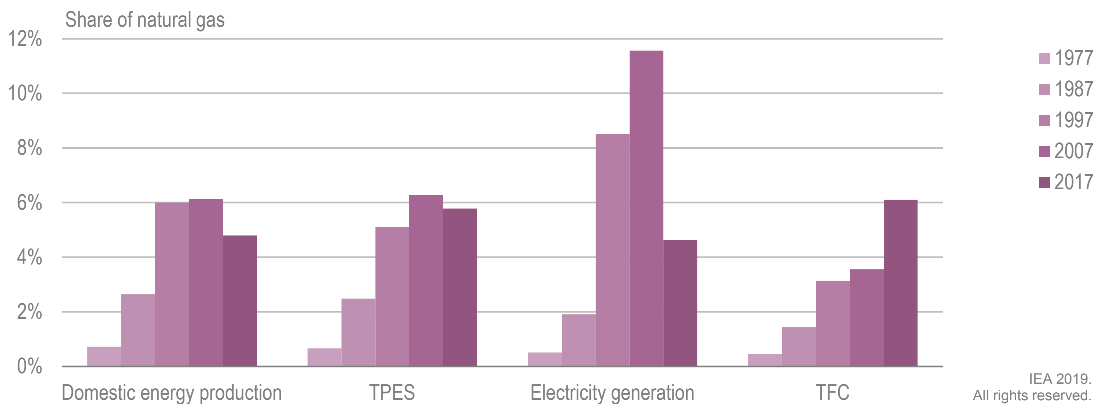
India aims to increase the share of natural gas to 15% of the energy mix by 2030 (PNGRB, 2013), which suggests a doubling of current demand and infrastructure needs, as part of a gas trading hub. This will require the availability of transport capacity across India, which will enable all market players to access LNG supplies. Under the Petroleum and Natural Gas Regulatory Board (PNGRB) Act 2006, gas pipelines were declared common carriers/contract, and non-discriminatory third-party access is mandatory. In practice, however, several companies maintain gas supply and transport activities, generating conflicts of interest that prevent a fully functioning third-party access regime. The future outlook for natural gas in India depends on the growth in demand, the evolution of the pricing regime, and the pace of gas infrastructure expansion. International experience (notably in the European Union) suggests that the key prerequisites to a fully functioning gas market are unbundling and domestic gas hub pricing that reflects local gas supply/demand fundamentals.

Supply and demand

Natural gas supply has been growing more slowly than total energy demand. Hence, the share of natural gas in total primary energy supply (TPES) has fallen during the past decade. In power generation, the share of gas is declining and newly installed gas power capacity remains underutilised.

The share of natural gas in total final consumption (TFC) is increasing, as industrial and residential consumption continue to grow (Figure 11.1).

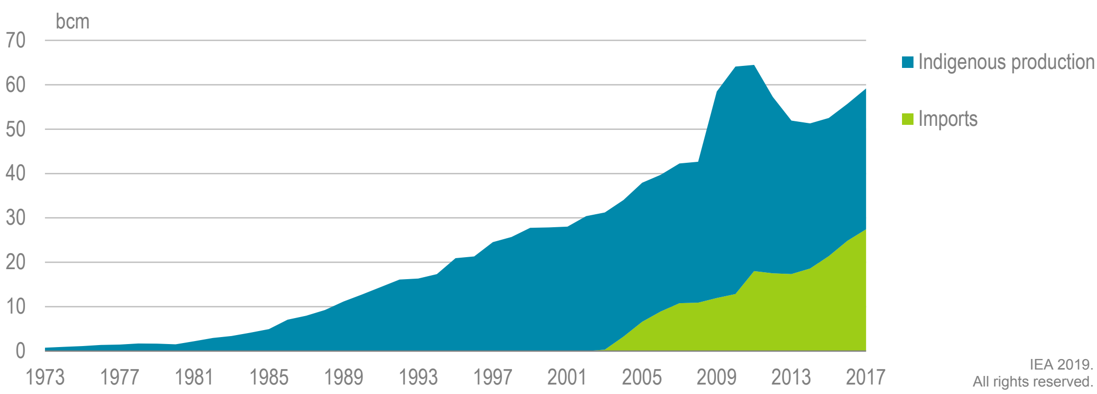
Figure 11.1 Share of natural gas in the energy system, 1977-2017



The share of natural gas in TFC has continuously increased amid rising industrial use; however, its share of power generation has declined.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 11.2 Natural gas supply by source, 1973-2017



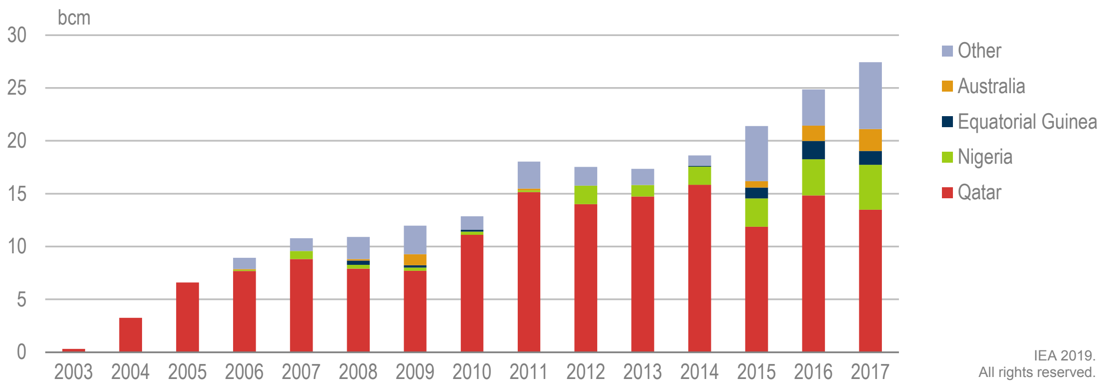
India's gas imports are increasing to supply the growing demand from industry. Imports covered nearly half of total gas supply in 2017.

Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics/.

In 2017 total gas supply was almost 60 bcm. Domestic production accounted for 54% of total supply and imports of LNG for the remaining 43% (Figure 11.2). With the exception of the period 2009-12, when production peaked at around 50 bcm, India's production has been stable at just above 30 bcm per year since the early 2000s.

Gas imports began in 2003 and have increased stepwise since, as India has expanded its LNG terminal capacity. In 2017 total natural gas imports were 27 bcm, of which 49% came from Qatar (Figure 11.3). India has diversified its supply sources in recent years and imported from more than 13 countries in 2017, including large shares from Nigeria, Equatorial Guinea and Australia.

Figure 11.3 Natural gas imports into India by country of origin, 2003-17



All of India's gas imports are LNG, with Qatar as the largest supplier.

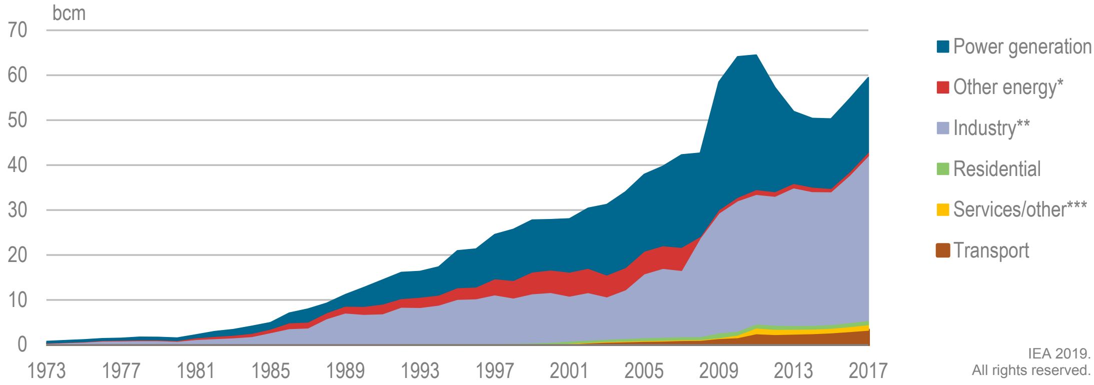
Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics/.

Industry and power generation together accounted for 90% of natural gas consumption in 2017 (Figure 11.4). The remainder is consumed in transport, the residential and services sectors and in oil and gas extraction. Nearly three-quarters of industrial consumption stems from non-energy purposes, as feedstock in petrochemical and fertiliser industries. Industrial gas consumption has more than doubled in a decade, with the biggest increase in 2008. Since then, natural gas has accounted for around 12% of total industrial energy consumption (including for non-energy purposes).

Gas power generation increased from 87 TWh in 2008 to between 113 TWh and 116 TWh in the period 2009-11, before falling to around 60 TWh in 2013, corresponding to the drop in domestic gas production. Gas power generation picked up somewhat to 71 TWh in 2017, but India still has a large installed capacity of gas power that is not fully utilised.

City gas distribution has increased in recent years under GoI policy, and India now has 5 million households using natural gas. Since 2014 the number of domestic piped natural gas connections, compressed natural gas (CNG) vehicles (3 million) and CNG stations (1 424 stations as at 30 April 2018) has more than doubled.

Figure 11.4 Gas consumption by consuming sector, 1973-2017



Thanks to the commissioning of new domestic gas production, industrial gas demand grew during 2009-11 and investment in new gas power generation boomed.

* *Other energy* includes consumption and losses in oil and gas production.

** *Industry* includes non-energy consumption.

*** *Services/other* includes commercial and public services, agriculture and forestry.

Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics/.

Gas production and reserves

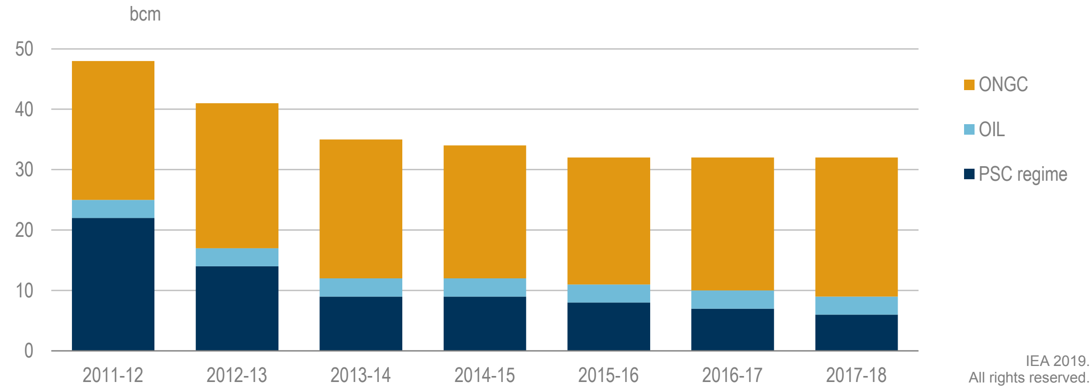
As of 1 April 2018 India has recoverable conventional natural gas reserves of 1 340 bcm, of which 61% are located offshore. Reserves held under the production-sharing contracts (PSC) regime account for 49% of total, whereas the two incumbent public service undertakings (PSUs), Oil and Natural Gas Corporation (ONGC) and Oil India Limited (OIL), have shares of 42% and 9%, respectively (MoPNG, 2018a).

As for unconventional resources, recoverable coal bed methane reserves are estimated at 108 bcm. Different estimates for shale gas resources range from 45 to 2 100 thousand cubic feet (or 1.3 to 59 thousand cubic metres), without information on recoverable reserves (MoPNG, 2018b).

Natural gas production has remained stable at around 30 bcm per year since 2013, following a spike in 2010-12 linked to the commissioning of new fields (D1-D3 and MA) and a steep decline in production at the Krishna Godavari Dhirubhai 6 (KG-D6) offshore field due to water and sand ingress in the reservoir (Figure 11.5), which led to the permanent shutdown of the MA Field.

The majority of natural gas exploration and production activities are carried out by two PSUs – ONGC and OIL. Private and foreign players entered Indian exploration and production in the late 1990s under the New Exploration Licensing Policy (NELP) framework. In 2017/18 the two PSUs accounted respectively for 71% and 9% of total natural gas production, the remaining 20% being produced under the PSC regime. Over two-thirds (67%) of natural gas production came from offshore fields, and in particular from the Mumbai Basin where ONGC-operated Bassein and Mumbai High fields accounted for 33% and 16% of total production, respectively.

Figure 11.5 Natural gas production by type, 2011-18



Source: MoPNG (2018a), *Indian Petroleum and Natural Gas Statistics 2017-18*, http://petroleum.nic.in/sites/default/files/ipngstat_0.pdf.

The Ministry of Petroleum and Natural Gas (MoPNG) projects a doubling of production by 2021/22 and significant changes in the production mix, as private producers under the PSC regime are expected to increase their output by five times (Table 11.1).

Table 11.1 Projected natural gas production (bcm)

	2017/18	2018/19	2019/20	2020/21	2021/22
ONGC	24.21	27.22	28.19	27.41	27.86
OIL	2.93	3.20	3.31	3.50	3.70
PSC	7.93	8.10	16.31	27.90	40.36
Total	**35.07**	**38.53**	**47.81**	**58.82**	**71.92**

Source: MoPNG (2018a), *Indian Petroleum and Natural Gas Statistics 2017-18*, http://petroleum.nic.in/sites/default/files/ipngstat_0.pdf.

The GoI sees strong potential for India to produce biogas from agricultural and other waste, and has set a target for the annual production of 15 Mt of compressed biogas by 2023 under the policy of Sustainable Alternative Towards Affordable Transportation (SATAT).

Institutions

The **Ministry of Petroleum and Natural Gas (MoPNG)** oversees the oil and gas industry, from exploration and production to distribution, marketing and pricing. It has authority over state-owned oil and gas companies (PSUs).

The **Directorate General of Hydrocarbons (DGH)** was established in 1993 under the administrative control of MoPNG and has several responsibilities, including the implementation of the NELP, HELP and Discovered Small Field Policy, as well as matters concerning PSCs and revenue-sharing contracts for discovered fields and exploration blocks. DGH is also engaged in opening up unexplored areas for future exploration and development of non-conventional hydrocarbon energy sources, for instance coal bed methane.

The **Petroleum and Natural Gas Regulatory Board (PNGRB)** was constituted in 2006 to protect the interests of consumers, to promote competitive markets and to regulate the refining, processing, storage, transport, distribution, marketing and sale of petroleum, petroleum products and natural gas (excluding production of crude oil and natural gas).

Gas infrastructure

India's natural gas transport network has 16 800 km of long-distance pipelines, which connect western, northern and south-eastern markets. Several new pipelines are under construction to the east and north-east of the country, adding another 15 000 km in the coming years, notably trans-regional gas pipelines. State-controlled GAIL owns and operates over two-thirds of the gas pipeline network. India has no international pipeline connections. There are currently no underground storage facilities for natural gas.

India has four LNG terminals located on the country's west coast and one new LNG terminal (Ennore) on the east coast, all with a total receiving capacity of 34 million tonnes per annum (Mtpa, or the equivalent of 37.4 bcm). This includes the expansion of the existing Dahej terminal. One more LNG facility has started up operations in 2019, Mundra, which was inaugurated in September 2018 and will bring up the total number of LNG facilities to six in 2020 with a total capacity of almost 40 Mtpa or 53 bcm (Table 11.2).

Table 11.2 Operational and under-development LNG terminals

Terminal	Commis-sioning	Promoters	Capacity (Mtpa)	Capacity utilisation	
		Operational		**2016/17**	**2017/18**
Dahej	2004	Petronet LNG	15	105.3%	105.3%
Hazira	2005	Hazira LNG	5	69.6%	58.9%
Dabhol	2013	Ratnagiri Gas and Power	1.7*	57.1%	64.9%
Kochi	2013	Petronet LNG	5	5.5%	12.2%
Ennore	2019	OIL	5.0	-	-
Dahej expansion	2019	Petronet LNG	2.4	-	-
Total operational			**34.1**	**76.9%**	**76.6%**
		Under development			
Dabhol (breakwater)	2019	Ratnagiri Gas and Power	3.3	-	-
Mundra	2019	GSPC LNG	4.9	-	-
Jaigarh FSRU	2020	H-Energy	4.0	-	-
Digha FSRU	2020	H-Energy	2.9	-	-
Jafrabad FSRU	2020	Swan Energy	5.0	-	-
Dhamra	2021	Adani, GAIL, OIL	4.9	-	-
Total under development			**25**	**-**	**-**

Notes: Data as of February 2019; FSRU = floating storage and regasification unit.

Sources: MoPNG (2018a), *Indian Petroleum and Natural Gas Statistics 2017-18*, http://petroleum.nic.in/sites/default/files/ipngstat_0.pdf, and information from project owners.

Several projects are under development and may add some 25 Mtpa of annual capacity, including the construction of a breakwater at the Dabhol terminal (which currently cannot receive cargoes during monsoon season). The new facilities will be offshore, using FSRU vessels. Jaigarh FSRU is expected to be the first to begin commissioning in January 2020 while Jafrabad is announced to start in the third quarter of 2020.

India is also investing abroad into the diversification of its supplies. In 2019 US Tellurian Inc. and Petronet LNG Limited of India agreed to a joint venture, with Petronet investing USD 2.5 billion in Tellurian's proposed Driftwood LNG export terminal in the United States in exchange for the rights to 5 Mt of LNG supply per year over 40 years. Most LNG imports are held under long-term contracts, mostly Petronet, GAIL and IOCL. GAIL India Limited and Gazprom successfully renegotiated their long-term LNG sale and purchase agreement reflecting the current global gas market dynamics (PIB, 2018).

Gas policy

Rising natural gas consumption in India is the result of several factors, including growing domestic supply, new gas infrastructure and rising gas production and imports.

Domestic gas is allocated to various sectors, including the city gas distribution sector, fertiliser production and the power sector, against projected gas production as per the approved field development plan and in accordance with the respective gas utilisation policies framed by the GoI. The actual gas supplied against the allocation to various sectors is made according to the availability of domestic gas. The government prioritises the allocation of natural gas first to the city gas sector (for residential use and use in transport), then the fertiliser sector, power generation and other sectors (PIB, 2019). This priority list of consumers constitutes the current gas utilisation policy of the GoI.

City gas distribution has priority as the government aims to increase gas demand by expanding the network to new cities and neighbourhoods. This policy is part of the GoI's overall effort to reduce the country's dependence on imported crude oil by 10% in 2022, partly by fuel switching in favour of natural gas. As of September 2018, 18 states and union territories (covering 96 cities, towns and districts) in India had city gas networks. Around 4.6 million Indian households are connected to the gas network, and there are over 26 000 commercial and 7 600 industrial connections. To expand the city gas network, the regulator PNGRB launched the 9th city gas distribution bidding round in April 2018 for 129 districts in 22 states and union territories. This round is expected to add 20 million households to the city gas network, along with 4 600 CNG stations for vehicles, by 2026. In November 2018 the 10th bidding round was announced, which concluded in March 2019. Once city gas network expansion under these two rounds is fully implemented, the network in India will cover 53% of its area and 70% of its population (PIB, 2018). The developer of a city gas network receives exclusivity to market gas in the region for up to ten years, and exclusivity for infrastructure development for 25 years.

The Achilles heel of India's natural gas sector remains gas-based power generation. India has a large installed gas power capacity, which is, however, underutilised. Lower-than-expected domestic natural gas production and the high price of imported gas (see Parliament of India [2019]) are the reasons for some 14 GW of stranded generation assets (see also Chapter 7 on electricity). Gas power generation peaked over three years from 2009 at 116 TWh, but fell back to levels of around 60-70 TWh owing to a sharp drop in domestic gas production (primarily from the KG-D6 fields following its shutdown by Reliance), thus leaving gas power plants running at a very low utilisation rate of 20%. In

2015 the GoI ran several reverse auctions to allocate subsidies to power generators for restarting their generation activity based on LNG imports.

Box 11.1 Gas demand increases in Gujarat

The GoI is focusing its efforts on developing city gas distribution to supply households and transport uses, as well as commercial and industrial customers. Successive bidding rounds have awarded development rights for the build-out of gas infrastructure in almost 200 geographical areas that collectively cover around half of the country's population. In late 2018 Prime Minister Modi announced the intention to have the network reach 70% of India's population in the next three years, a key commitment under the government's vision for a "gas-based economy" (PNGRB, 2013). To this end, the government has also made pledges to expand the number of filling stations providing CNG sevenfold, to a total of 10 000 within the next decade. These national efforts to expand India's gas market are underpinned by significant investments in gas transport; key infrastructure projects, such as the Urja Ganga pipeline, are designed to bring gas into some of India's most populous states (West Bengal, Bihar and Uttar Pradesh).

India's policy ambitions for gas have frequently fallen short, but the case of Gujarat shows that gas can gain significant market share under the right conditions. Natural gas accounts for up to one-quarter of the state's energy mix, well above the national average; this is largely due to the discovery of offshore gas resources and local authorities incentivising both gas-fired power plants and fertiliser plants. A densely populated region, Gujarat is geographically far from coal reserves in the eastern part of the country, putting a higher transport cost premium on coal; its coastal location has also enabled the construction of an LNG import terminal. Thanks to this favourable combination of geography, supply and supportive governance, Gujarat is set to become the first Indian state to be completely covered by a gas distribution network.

Markets and regulation

Upstream

India's oil and gas upstream sector was opened to private and foreign companies under the NELP. Nine bidding rounds were held under the NELP between 1999 and 2010, with a total of 254 blocks awarded – of which 159 were awarded to PSU or PSU-led joint ventures, and 95 to private companies or joint ventures (DGH, 2019).

The HELP regime was introduced in 2016 and included four key market design changes compared to NELP:

- A single licence for exploration and production was introduced.
- The Open Acreage Licensing Policy (OALP) provides freedom to select and bid on any exploration block without waiting for a formal government bidding round.

- A new form of contract, the revenue-sharing contract, was introduced as a replacement to the production-sharing contract, a move from profit sharing to revenue sharing which simplifies government monitoring of costs.
- Pricing and marketing freedom was introduced subject to a ceiling price for production from discoveries in deepwater, ultra-deepwater and high pressure–high temperature fields. This ceiling price is set by the MoPNG and updated twice a year.
- A series of measures target the improved functioning of DGH as a single clearance point with standardised guidelines and data accessibility. The HELP also allows bidders to access the National Data Repository to assess the prospects of any area and propose their own area (block) for bidding.

Prior to the 2014 pricing reform, different price regimes co-existed, depending on the type of supply and the class of end user. Domestic production pricing was segmented between fields with a government-fixed administrated price regime on a cost-plus basis, and individual production-sharing terms under the NELP and pre-NELP regimes. LNG import tariffs were set bilaterally based on specific contractual formulae or international spot prices. In 2014 a new pricing mechanism was adopted (PIB, 2014a) based on a consumption-weighted average basket of international natural gas prices for the United States, Canada, Europe and the Russian Federation ("Russia"), with a view to reducing links to high-price areas, notably Japan netback LNG prices. This price is reviewed every six months, based on price and volume data for the previous four quarters with a lag of one quarter. The gas price, however, does not reflect the local demand–supply structure of the gas market in India, such as gas production costs for new discoveries or consumer needs.

Onshore India has coal bed methane potential, estimated at some 2 600 bcm, in blocks spread out over 11 states. Of these blocks, 33 have been awarded at an average size of about 140 km^2. Four of these blocks are currently producing, with a total output of some 700 mcm per year, or some 2% of domestic gas production. The development of shale gas within awarded blocks is allowed in principle, as there is no special regime for shale gas. The availability of land and water, however, are barriers to large-scale shale gas development.

Midstream

The PNGRB regulates gas transport access and transport rates, access to distribution and city gas networks (not gas tariffs), as well as authorisation and registration of companies active in LNG, gas storage, city gas distribution and transport.

The gas pipeline network is open to third parties. An online portal was launched by GAIL in 2018 to provide transparent open access and to apply for booking of capacity. However, GAIL is not unbundled and controls a large capacity of pipeline and gas supplies. Besides, pipeline tariffs are cumulative, which can lead to substantial costs for long-distance transport due to the addition of transit zones and tariffs (also known as "pancaking"). GAIL, which accounts for a large majority of network ownership and operations, has proposed the introduction of a uniform "postage stamp" tariff regime to reduce the end price of gas.

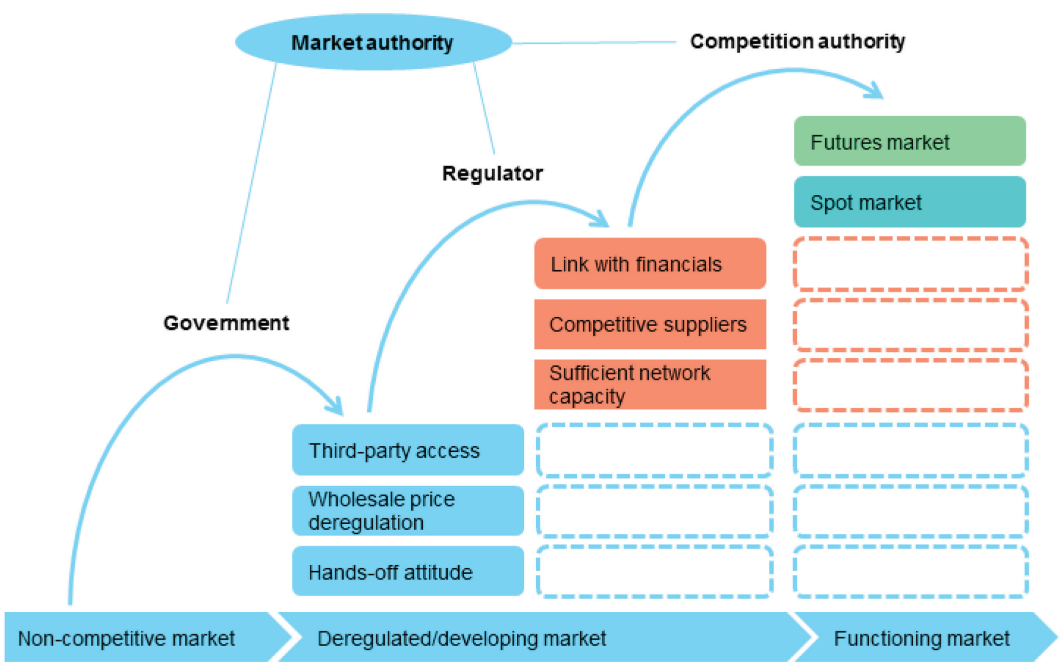
LNG terminals are not open to third parties. To enable open access to LNG import facilities, relevant rules have been proposed (Order no. L-12018/6/2009 GP II, dated 30.10.2012 under the PNGRB Act 2006). These rules have defined the eligibility conditions. PGNRB issued a draft regulation in 2018 for the building and operation of LNG terminals, which stipulates that new terminals would have to offer at all times 20% of their short-term (less than five years) uncommitted regasification capacity, or a minimum of 0.5 Mt per year, to third parties (PGNRB, 2018).

Downstream

The current gas retail market in India covers around 5 million homes and 1 500 CNG stations. Consumers are not able to choose their supplier and pricing is based on the new international price basket for LNG imports and gas production development. Natural gas is not included in the Goods and Services Tax (GST) and is therefore subject to many state and central taxes and duties on top of midstream charges.

India has been envisaging the creation of a natural gas hub for a long time. Several characteristics define a gas hub. A hub facilitates gas wholesale trading as a marketplace and defines a hub gas price. The network operation, the availability of ample gas supplies and the legal framework are central to the hub design. As an independent and neutral player, the network operator facilitates the market place including the ability for all market participants to book, allocate and transport capacity. For that, the unbundled operator secures independent management and third-party access for market participants (Figure 11.6). This requires transparent rules for capacity allocation, congestion management and balancing.

Figure 11.6 Market reform in the gas sector



The dominant trend in Europe has been the development of virtual trading hubs (only the Belgian Zeebrugge and Austrian Central European Gas Hub are physical hubs where the network configuration allows a significant amount of physical gas sales and purchases, including gas storage). The virtual hub brings together all delivery points in one entry–exit zone. The network operator of the zone delivers the transport service between entry and exit points and balancing services. Critical elements are the legal and regulatory framework for the gas market, alongside the wholesale trading rules (Figure 11.6). India's gas market will need to further develop from long-term contracts to short-term contracts and flexible spot-market and futures products. The regulator and a competition authority will need to play a greater role to promote supplier competition, sufficient network capacity and flexible trading products.

Security of gas supply

India's growing dependence on imported natural gas, reaching 43% of the total gas supply in 2016 compared to 29% in 2006, requires more attention from policy makers to assure the security of gas supply. Key factors that constitute natural gas security for India are:

- the pace of development of domestic production
- the diversity of the gas and LNG import portfolio
- pipeline import options
- the availability of seasonal storage
- the availability of additional LNG volumes.

Domestic gas production

Gas supply security in India has been mainly a domestic supply issue, with a shortfall caused by the KG-D6 production shutdown and slower than expected development of the exploration and production sector over the past decade in spite of objectives to double domestic output. India does not have spare capacity that it could use during a supply emergency.

Diversity of the LNG import portfolio

India has increasingly diversified its supply sources of LNG in recent years. In 2016, 60% of India's LNG imports came from Qatar, down from 85% in 2014. Other sources of India's LNG include Nigeria, Equatorial Guinea and Australia.

Although most of the LNG terminals are located along the west coast, India's first east-coast LNG terminal (Ennore) was commissioned in early 2019. The gas-fired power plants in the eastern region are already connected to the existing gas grid, and gas may be supplied to these power plants from various gas sources including LNG import terminals located on the west coast. (However, gas use in power generation based on LNG imports is not a supply issue in India, but a pricing issue.)

The International Energy Agency (IEA) analysed the readiness and timeliness of LNG sources to cover for potential supply disruptions from supplying countries and/or surges in demand (IEA, 2018). In this global study, several factors were considered including LNG as a proportion of gas consumption and gas import diversity (measured by the Herfindahl–Hirschman index). Based on these metrics, countries were grouped into four categories: exposed gas importers, exposed LNG importers, diversified gas importers and diversified

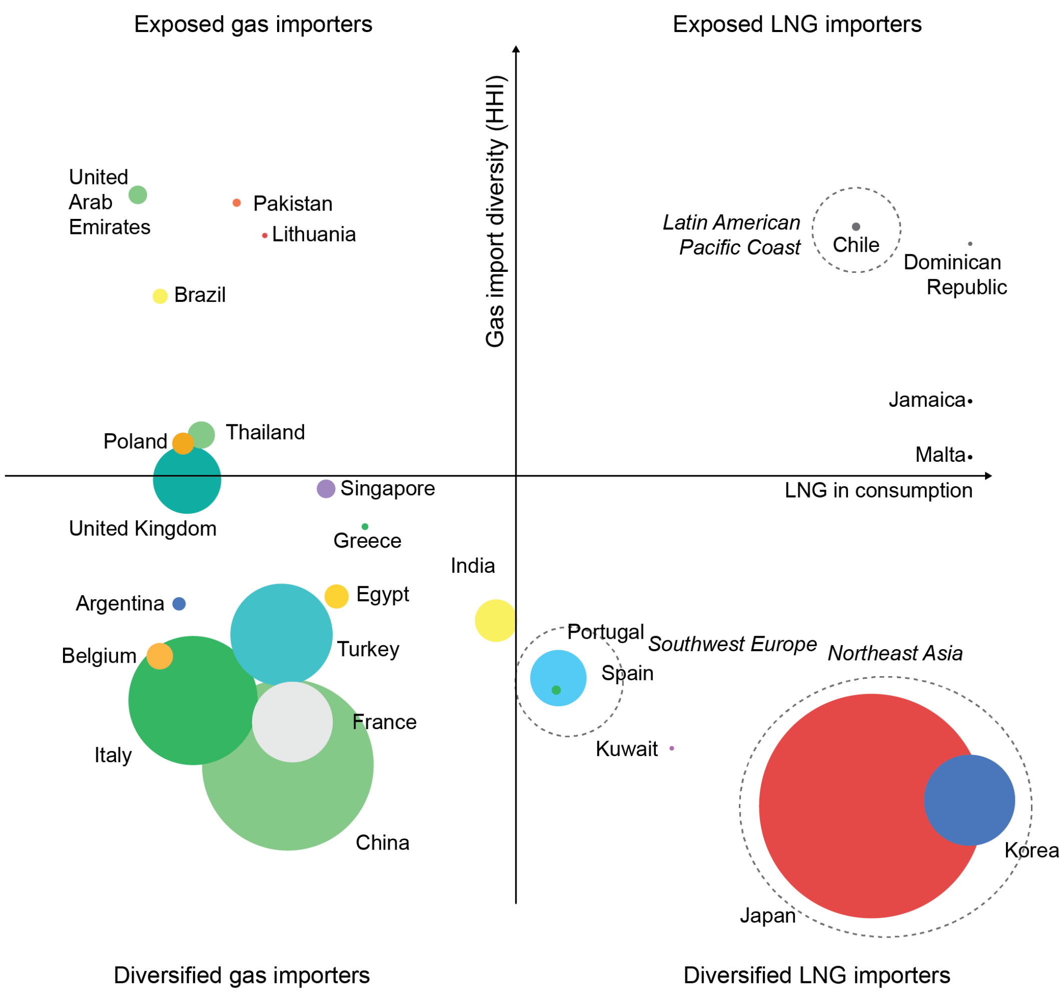
LNG importers. India falls into the category of diversified gas importer, as opposed to being an exposed gas importer, indicating that it largely meets its natural gas requirements through domestic production, and its imports are fairly diversified in source.

In Figure 11.7, the horizontal axis indicates the share of LNG in gas consumption (LNG dependence) from 0 to 100%; the vertical axis shows the gas import diversity; and the bubble size represents the size of net gas imports in 2017.

India's state-owned oil and gas companies have signed long term LNG contracts with companies based in a range of countries, including Qatar, Russia, Australia and the United States (PIB, 2018). As illustrated in Figure 11.7, India is moving from being a diversified gas importer in 2018 to a diversified LNG importer, as LNG imports already cover around 50% of natural gas consumption in 2019.

If additional imports of LNG are not sourced from a diverse set of producers, India risks moving closer to the exposed LNG importer category. The GoI is making efforts to prevent this by diversifying its portfolio with new long-term contacts that have been signed by the PSUs.

Figure 11.7 Security of supply position of India in the globalising LNG market, 2018



Source: IEA (2018), *Global Gas Security Review 2018*.

Pipeline import options

There have been some efforts to establish a pipeline from Iran via Pakistan to India (IPI Pipeline), but it was put on hold in 2008 following sanctions against Iran by the United States. Since then, a rival pipeline from Turkmenistan via Afghanistan and Pakistan to India (TAPI Pipeline) has been studied. While both pipelines have geopolitical concerns for India as they cross Afghanistan and/or Pakistan, the latter has seen some progress. The ground-breaking ceremony of the 1 800 km long TAPI Pipeline took place in December 2015. The pipeline consortium – the TAPI Pipeline Company – was set up in 2014 with shareholdings by Turkmenistan (85%), India (5%), Pakistan (5%) and Afghanistan (5%). The project is stated to be completed within seven years, with commercial operations targeted to begin in 2022 (PIB, 2016) and is due to supply some 14 bcm per year for 30 years (PIB 2014b).

Another international pipeline is the Middle East to India Deepwater Gas Pipeline (MEIDP), being proposed by the South Asia Gas Enterprise (SAGE), from Oman to India with a length of 1 200 km and a maximum depth of 3 500 metres below sea level. However, as of 2015 this pipeline is no longer under the consideration by the GoI (PIB, 2015). SAGE has also presented the possibility of this undersea pipeline being used to import gas from Iran into India.

Availability of additional LNG volumes

In the short term, additional LNG volumes can plug shortfalls arising from supply disruptions. Additional supplies can come from various sources including uncontracted LNG available in spot markets, flexible-destination LNG and unused LNG capacity (the difference between net capacity and output).

As per IEA analysis in 2018, while contracted LNG accounted for the majority of global trade, flexible LNG amounted to approximately 150 bcm in 2017. Additionally, unused LNG liquefaction capacity was small at only 34 bcm globally. The majority of the unused capacity was located in Algeria, Angola, Malaysia and the Russian Federation (IEA, 2018).

India has no dedicated policy or emergency response strategy to address an unexpected shortfall in, or disruption to the supply of, natural gas by acquiring additionally available LNG from the global markets. A situation such as the shutdown of domestic production is an illustrative example that can trigger the need for action on security of supply, including changes in gas allocation policy, imports and pricing. In most IEA countries, the obligation to supply natural gas to priority consumers (such as households, hospitals or other public services) is borne by the suppliers/shippers, and it is up to them to fulfil their obligations with adequate means. This normally based on underground or LNG storage, but can also be spot procurement as a last resort.

Availability of seasonal storage

India's gas demand does not have a strong seasonal component because there is no winter heating load. However, transport and market integration across India does make storage an important factor in gas security of supply. Storage of natural gas can help address shortages, disruption to supply and fluctuations in industrial demand. There is a range of options to store natural gas underground, including in depleted natural gas or oil fields, aquifer reservoirs and salt caverns. Additionally, LNG can be stored in above-ground storage tanks. Globally, natural gas storage has been developed in the

United States, Canada and in Europe, particularly Germany, France and Italy. To date, India does not have any underground natural gas storage infrastructure, but the government has constituted a committee of ONGC, GAIL, Petronet LNG and the Oil Industry Development Board to assess the need to develop underground gas storage.

Box 11.2 International experience – gas reserves

In an increasingly globalised, liquid and short-term market, gas storage is competing with other flexibility products amid falling prices at international gas hubs. As well as hub-related products (forward contracts, capacity bundles etc.), other flexibility sources are available: swing gas production, import contracts, line pack, swaps, interruptible contracts and LNG.

While governments may be tempted to secure gas storage capacity for emergency situations in their territory, such a possibility may not be appealing for several reasons relating to cost, administration, availability and market distortion.

Gas needs to be stored in either high-pressure or liquid form. Physical stocks for an emergency are removed from the market and are held by the government or by industry under a public-service obligation. Several EU countries have storage obligations or alternative-fuel obligations, including a government stockholding agency in Hungary and gas stockholding obligations in Denmark, Italy, Poland, Portugal, the Slovak Republic and Spain. In addition, France has strengthened the regulatory framework with regard to keeping gas in storage at appropriate levels. The contribution of gas storage facilities to security of supply and emergency situations, however, varies greatly depending on their characteristics (depleted gas field, aquifer or salt cavern) and on withdrawal rates.

Investment into new gas storage facilities is also expensive, particularly compared to oil stocks (IEA, 2014):

- An underground gas storage facility costs five to seven times more than underground oil storage, also because of the capital cost of "cushion gas" (depending on the type of storage it can be up to 80% for aquifers, 50% for depleted fields or 25% of the capital cost for salt caverns).
- An LNG storage facility can be even more expensive, up to 10 times the cost of stocks in oil tanks and 50 times the cost of underground oil storage (caverns).
- The variable costs of maintaining gas in storage are estimated to be around 10% to 20% of the capital cost per year per facility.

Any call for public emergency stockpiling would have a direct impact on commercial storage and may deter commercial storage investment. Besides the cost, other non-commercial barriers exist. Gas storage requires time for permitting, financing and construction, unless the country has a field nearing depletion. Not all countries have geological conditions suitable for underground gas storage and thus would rely on LNG tanks, where available.

Assessment

Gas supply in India started to increase in the 1980s, largely driven by increased demand in the industrial (fertiliser production) and residential sectors, reaching 60 bcm of total gas demand in 2017. Gas supply has increased almost linearly for three decades. In 2017 the share of gas in TPES was 6%, while the share of gas in the global energy mix was 23.4%. India has a target to increase the role of natural gas to reach 15% of the energy mix by 2030. Gas can play an essential role in supporting India's sustainable development, but availability and affordability remain concerns in India.

India is expanding its gas distribution network rapidly, having already held ten bidding rounds for city gas network expansion; after completion, more than half of India's territory will be covered and 70% of its population could be connected to a network, as natural gas is cheaper than LPG. Increased use of gas in cities would also reduce air pollution. Currently around 5 million households are connected to the grid.

In transport, piped natural gas and CNG are gaining ground. Industry is the largest consumer of natural gas in India, accounting for 62% of total consumption in 2017. Most of this is for production of fertilisers and petrochemicals. Power generation is the other main gas consumer, at around 28% of total demand. The capacity of the power sector to absorb more gas is large, as some 25 GW of gas-fired power capacity stands idle. Despite electricity shortages, the electricity distribution companies cannot afford to buy the relatively expensive gas-fired electricity (imported LNG is much more expensive than coal for firing power plants) because their electricity retail prices are kept artificially low due to government intervention. The anticipated tripling of variable renewable generation (wind and solar photovoltaic) could be supported by the greater penetration of gas-fired power to balance the variability of these renewable sources.

Gas-fired power generation capacity was built in anticipation of rising volumes of relatively cheap domestic gas production, a proportion of which had been centrally allocated by the government for use in power generation. This was originally set to a level of 75% of gas production to cover the demand in the power sector, but domestic production did not materialise at scale, leaving several power plants stranded, unable to afford higher-priced imported gas. In January 2019 the Ministry of Power's Standing Committee on Energy concluded that frequent policy shifts on domestic gas allocations, coupled with disappointing domestic production, have made the business case for gas-based capacity untenable (Parliament of India, 2019). The GoI is considering the reintroduction of auctions of gas at subsidised prices to alleviate the supply crunch to the stranded power generators (see Chapter 7 on electricity). During 2015/16 the GoI ran an e-auction scheme for regasified LNG over two rounds, but this was discontinued amid strong demand.

Domestic gas production has been relatively stable at around 30 bcm in recent decades, down from the peak of 50 bcm. Domestic production covers just over half total gas supplies; the rest is met by LNG imports. India started importing LNG in 2003 and imports have been steadily increasing since. LNG regasification capacity in India is increasing rapidly: with the commissioning of Ennore LNG in 2019 and forthcoming start-up of Mundra LNG terminal, there will be 6 LNG terminals in the country with a total LNG import capacity of about 53 bcm.

India expects domestic production to gradually increase as a result of its policy to attract foreign investors for offshore blocks. To reduce its dependence on imported oil and gas and to promote domestic production in India, the GoI implemented the HELP. The first round of the HELP attracted mostly Indian companies; a second round is underway. If this second round does not attract more foreign bidders, the GoI should evaluate the conditions of the HELP and other barriers, including pricing, access to transmission and taxation in India.

One challenge is gas pricing: linking domestic gas prices to a basket of (very low) international reference prices has reduced incentives for domestic producers to increase supply. The reforms that allow marketing freedom to new supplies might help. However, there is still very low interest from new upstream companies to bid for acreage, given the competition from incumbent producers that sell gas at below its cost of production. Access to LNG facilities currently needs to be negotiated with the owner; however, the government is considering establishing an open access regime for these facilities. Whether these facilities will be fully utilised, or end up as stranded assets, very much depends on the pricing regime for gas.

The price of domestic gas is lower than that of (imported) LNG and is defined by indexation to international markets. Since India sources around 50% of its LNG imports via long-term contracts and the other half from spot markets, the price difference between oil-linked and spot gas is very important for Indian buyers. As spot gas has become noticeably cheaper, buyers of oil-indexed gas are likely to seek contractual renegotiations. GAIL and Petronet have renegotiated contracts with RasGas and others (Australia, Russia) to achieve lower prices (by lowering the "slopes" that dictate the strength of the oil–gas price link in oil-indexed long-term contracts). A similar trend happened in Europe, which helped create the conditions for spot market-based pricing of gas.

For natural gas to compete in India, costs have to come down, including through rationalisation of subsidies for coal and LPG and adjustment of the GST. Since natural gas does not fall under the GST, gas consumption is taxed at several state and central government levels, in addition to the gas transport tariffs. Bringing natural gas under the GST and introducing a postage stamp gas transport tariff would reduce these costs and create a level playing field with other fuels. Overall, India's latest 2014 gas price mechanism focuses very much on reducing the price level rather than the creation of a market-based system to reflect the domestic supply–demand structure in India.

There is no trading hub yet in India, although its creation has been suggested for 2019. The creation of a gas hub would allow transparent price discovery on the basis of buyers and sellers interacting in an open market, and has the potential to remove the multiple price regimes in India. The GoI should therefore go ahead and implement the creation of a gas hub. International experience suggests that a virtual trading hub with an entry–exit regime based on transmission capacity is highly suited for market areas with limited transmission capacity and limited domestic production but rising LNG imports. The experience in the European Union can be very instructive for India. It has taken more than a decade to create a liquid natural gas market across 28 EU states.

Another challenge is unclear regulatory oversight of midstream/downstream activities. India has a third-party access regime in place, at transport tariffs set by the PNGRB. New gas discoveries and LNG imports have to use, in most cases, the transmission networks of the incumbents, which is not guaranteed in practice. GAIL operates 68% of the transmission network and several regional gas pipeline networks. GAIL's "Natural Gas Pipeline Open Access System" platform was launched in 2018 to provide market access and transparency to third parties. According to the platform, in September 2019 capacity available for third-party access did not exceed 25% in most cases. However, only in a handful of instances was this TPA capacity partially booked. Only firm capacity agreements are available, with no mention of secondary capacity or flexibility of booking, such as use-it-or-lose-it, to avoid any risk of contractual congestion. The MoPNG announced the unbundling of GAIL in 2019, which should help create an independent transmission system operator to foster liquid gas trades across India. This would help bring further flexibility and transparency to the system. Creating a single transmission system operator would also be an option (most operators being State owned companies).

At the same time, there are overlapping competencies across government, including PNGRB, the MoPNG, NITI Aayog and state-level authorities (KAPSARC and TERI, 2018). Together with frequent policy changes, these factors can deter investment. The IEA recommends that the GoI clarifies roles and responsibilities, and institutionalises lines of communication between administrative bodies, for instance by strengthening regulatory oversight and independence.

Overall, the policy of increasing the role of gas is commendable, as it results in health benefits (when substituting for traditional biomass for cooking) and decreased greenhouse gas emissions (when substituting for coal in power generation). As the share of natural gas is on the rise, it is advisable to embark on developing a gas security policy based on a well-functioning domestic gas market and robust gas infrastructure. The GoI should therefore promote the development of a functioning gas market that can allow supply to meet demand. This includes market-based price discovery, robust gas infrastructure, an independent regulator, third-party access to infrastructure, and competition among multiple buyers and sellers.

Recommendations

The Government of India should:

- Foster the creation of a liquid market for natural gas in India, gradually moving from gas allocation and multiple pricing regimes to the creation of a gas hub, so that domestic gas and LNG imports can be used in the most efficient way and competition can flourish.
- Strengthen and clarify the roles and responsibilities with regard to the regulatory supervision of natural gas market activities (upstream, midstream and downstream) to ensure a non-discriminatory access regime to pipeline capacity so that both LNG imports and new gas discoveries can find their way to markets and investment in gas transport and storage is encouraged.
- Ensure gas is treated on a level playing field with other fuels for taxation and is included under the GST, as the country strives to increase the share of gas in total energy supply.

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ANNEX A: Organisations visited

Review team and preparation of the report

This in-depth review was carried out in 2019 after the review team's visit to India from 13 to 21 January 2019. In New Delhi the team met with central government officials and regulators, industry associations and stakeholders in the public and private sectors as well as other organisations and interest groups, all of whom helped the team identify the key challenges facing energy policy makers in India.

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The review was carried out by Ms Sylvia Beyer and co-ordinated by Mr Tristan Stanley with the invaluable assistance of Ms Astha Gupta and Mr Siddharth Singh, who supported the review and the drafting of the report, as IEA India programme members in New Delhi at the NITI Aayog.

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The report was prepared under the guidance of the IEA Head of Energy Policy and Security Division, Mr Aad van Bohemen. Valuable comments and inputs were provided by the review team members and the IEA staff, including Mr Paolo Frankl, Mr Edwin Haesen, Mr Alejandro Hernandez Cesar, Mr Andrew Prag, Ms Toril Bosoni and Ms Kristine Petrosyan, Mr Michael Waldron, Ms Lucila Arboleya Sarazola, Mr Jacopo Tattini and Mr Jacob Teter on transport and railways in India, and Ms Astha Gupta and Mr Siddharth Singh.

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Organisations visited

NITI Aayog

Ministry of Power (MoP)

Central Electricity Authority (CEA)

Central Electricity Regulatory Commission (CERC)

Bureau of Energy Efficiency (BEE)

Power Grid Corporation of India Limited (Powergrid)

Power System Corporation Limited (POSOCO)

National Thermal Power Corporation (NTPC)

National Hydro Power Corporation (NHPC)

Power Finance Corporation (PFC)

Rural Electrification Corporation (REC)

Ministry of New and Renewable Energy (MNRE)

Solar Energy Corporation of India (SECI)

National Institute of Solar Energy (NISE)

National Institute of Wind Energy (NIWE)

Cement Manufacturers Association (CEM)

Indian Captive Power Producers Association (ICPPA)

Steel Authority of India

Indian Renewable Energy Development Agency (IREDA)

India Wind Turbine Manufacturers Association

Indian Solar Manufacturers Association

Alliance for Energy Efficient Economy

Confederation of Indian Industry

Ministry of Road Transport and Highways (MRTH)

Ministry of Science and Technology (MoST)

Ministry of Environment, Forests and Climate Change (MoEFCC)

Ministry of Finance

Ministry of Petroleum and Natural Gas (MoPNG)

Petroleum and Natural Gas Regulatory Board (PNGRB)

Oil and Natural Gas Corporation (ONGC)

Indian Oil Corporation Limited (IOCL)

GAIL India Limited

Ministry of Coal (MoC)

Ministry of Railways

Coal India Limited (CIL)

Coal Controller’s Organisation

Tata Steel Limited

Suzlon Energy Limited

Tata Power Solar

Renew Power

GE

Shell India

BP

International Institute for Sustainable Development (IISD)

Shakti Sustainable Energy Foundation

The Energy and Resources Institute (TERI)

Council on Energy, Environment and Water (CEEW)

The Brookings Institute

Centre for Policy Research

World Energy Resources Institute (WRI)

Centre for Science, Technology and Policy (CSTEP)

Embassy of Switzerland

Embassy of Sweden

British High Commission

Delegation of the European Commission

World Bank

Asian Development Bank (ADB)

Kreditanstalt für Wiederaufbau (KfW)

UNIDO

GIZ

USAID

ANNEX B: Energy balances and key statistical data

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2016	2017	2018p
TOTAL PRODUCTION		**144.07**	**280.49**	**350.79**	**503.81**	**551.08**	**554.44**	**..**
Coal		32.74	93.34	130.64	212.88	268.07	269.84	288.52
Peat		-	-	-	-	-	-	..
Oil		7.35	35.32	37.24	43.14	41.21	41.20	40.25
Natural gas		0.63	10.57	23.07	42.97	25.86	26.60	26.78
Biofuels and waste[1]		100.24	133.48	148.85	185.25	188.04	187.14	..
Nuclear		0.62	1.60	4.40	6.84	9.88	9.99	..
Hydro		2.49	6.16	6.40	10.74	11.85	12.19	..
Wind		-	0.00	0.15	1.69	3.85	4.39	..
Geothermal		-	-	-	-	-	-	..
Solar/other		-	0.01	0.04	0.30	2.32	3.09	..
TOTAL NET IMPORTS[2]		**16.47**	**29.96**	**89.08**	**200.18**	**308.53**	**324.53**	**..**
Coal	Exports	0.26	0.04	0.58	1.21	0.76	0.64	0.52
	Imports	-	4.17	14.80	70.54	110.17	118.76	131.68
	Net imports	-0.26	4.13	14.22	69.33	109.41	118.13	131.16
Oil	Exports	0.19	2.77	8.20	61.44	70.59	71.81	..
	Imports	17.72	30.17	85.30	184.93	253.07	259.52	..
	Int'l marine and aviation bunkers	-0.81	-1.68	-2.36	-4.56	-5.35	-5.59	..
	Net imports	16.73	25.72	74.75	118.93	177.13	182.12	..
Natural gas	Exports	-	-	-	-	-	-	-
	Imports	-	-	-	11.44	22.11	24.42	25.53
	Net imports	-	-	-	11.44	22.11	24.42	25.53
Electricity	Exports	0.00	0.01	0.02	0.01	0.58	0.62	..
	Imports	-	0.12	0.13	0.48	0.48	0.48	..
	Net imports	-0.00	0.12	0.11	0.48	-0.09	-0.14	..
TOTAL STOCK CHANGES		**-0.76**	**-4.71**	**1.07**	**-3.20**	**-6.81**	**2.97**	**..**
TOTAL SUPPLY (TPES)[3]		**159.78**	**305.74**	**440.93**	**700.78**	**852.81**	**881.95**	**..**
Coal		31.51	92.70	145.92	279.03	372.28	390.95	409.33
Peat		-	-	-	-	-	-	..
Oil		24.28	61.10	111.99	162.07	216.74	223.32	..
Natural gas		0.63	10.57	23.07	54.40	47.98	51.02	53.39
Biofuels and waste[1]		100.24	133.48	148.85	185.23	188.01	187.14	..
Nuclear		0.62	1.60	4.40	6.84	9.88	9.99	..
Hydro		2.49	6.16	6.40	10.74	11.85	12.19	..
Wind		-	0.00	0.15	1.69	3.85	4.39	..
Geothermal		-	-	-	-	-	-	..
Solar/other		-	0.01	0.04	0.30	2.32	3.09	..
Electricity trade[4]		-0.00	0.12	0.11	0.48	-0.09	-0.14	..
Shares in TPES (%)								
Coal		*19.7*	*30.3*	*33.1*	*39.8*	*43.7*	*44.3*	..
Peat		-	-	-	-	-	-	..
Oil		*15.2*	*20.0*	*25.4*	*23.1*	*25.4*	*25.3*	..
Natural gas		*0.4*	*3.5*	*5.2*	*7.8*	*5.6*	*5.8*	..
Biofuels and waste[1]		*62.7*	*43.7*	*33.8*	*26.4*	*22.0*	*21.2*	..
Nuclear		*0.4*	*0.5*	*1.0*	*1.0*	*1.2*	*1.1*	..
Hydro		*1.6*	*2.0*	*1.5*	*1.5*	*1.4*	*1.4*	..
Wind		-	-	-	*0.2*	*0.5*	*0.5*	..
Geothermal		-	-	-	-	-	-	..
Solar/other		-	*0.0*	*0.0*	*0.0*	*0.3*	*0.4*	..
Electricity trade[4]		-	-	-	*0.1*	-	-	..

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p**
TFC	**143.37**	**242.88**	**314.09**	**484.50**	**569.37**	**591.23**	**..**
Coal	20.45	38.24	33.15	87.07	96.11	101.15	..
Peat	-	-	-	-	-	-	..
Oil	19.91	50.17	94.47	135.03	184.52	195.52	..
Natural gas	0.29	5.64	9.67	27.21	33.39	36.10	..
Biofuels and waste[1]	97.95	130.34	144.42	172.37	159.43	157.53	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	0.01	0.04	0.29	0.71	0.85	..
Electricity	4.77	18.49	32.35	62.52	95.22	100.09	..
Heat	-	-	-	-	-	-	..
Shares in TFC (%)							
Coal	*14.3*	*15.7*	*10.6*	*18.0*	*16.9*	*17.1*	..
Peat	-	-	-	-	-	-	..
Oil	*13.9*	*20.7*	*30.1*	*27.9*	*32.4*	*33.1*	..
Natural gas	*0.2*	*2.3*	*3.1*	*5.6*	*5.9*	*6.1*	..
Biofuels and waste[1]	*68.3*	*53.7*	*46.0*	*35.6*	*28.0*	*26.6*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	*0.0*	*0.0*	*0.1*	*0.1*	*0.1*	..
Electricity	*3.3*	*7.6*	*10.3*	*12.9*	*16.7*	*16.9*	..
Heat	-	-	-	-	-	-	..
TOTAL INDUSTRY[5]	**38.40**	**80.03**	**110.21**	**193.25**	**239.28**	**250.95**	**..**
Coal	9.73	26.38	25.77	74.97	84.46	89.27	..
Peat	-	-	-	-	-	-	..
Oil	8.26	16.54	36.06	36.77	56.48	58.20	..
Natural gas	0.27	5.52	9.19	24.62	29.09	31.42	..
Biofuels and waste[1]	16.90	22.51	25.57	29.37	31.59	31.95	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	0.00	0.00	0.02	0.04	0.05	..
Electricity	3.24	9.08	13.62	27.51	37.62	40.07	..
Heat	-	-	-	-	-	-	..
Shares in total industry (%)							
Coal	*25.3*	*33.0*	*23.4*	*38.8*	*35.3*	*35.6*	..
Peat	-	-	-	-	-	-	..
Oil	*21.5*	*20.7*	*32.7*	*19.0*	*23.6*	*23.2*	..
Natural gas	*0.7*	*6.9*	*8.3*	*12.7*	*12.2*	*12.5*	..
Biofuels and waste[1]	*44.0*	*28.1*	*23.2*	*15.2*	*13.2*	*12.7*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	-	-	-	..
Electricity	*8.4*	*11.3*	*12.4*	*14.2*	*15.7*	*16.0*	..
Heat	-	-	-	-	-	-	..
TRANSPORT[3]	**12.53**	**20.75**	**31.92**	**64.80**	**91.18**	**98.22**	**..**
OTHER[6]	**92.45**	**142.10**	**171.96**	**226.45**	**238.91**	**242.06**	**..**
Coal	5.13	9.67	7.38	12.10	11.65	11.88	..
Peat	-	-	-	-	-	-	..
Oil	4.86	15.42	27.35	36.04	41.36	43.56	..
Natural gas	0.02	0.12	0.40	1.22	1.75	1.86	..
Biofuels and waste[1]	81.05	107.83	118.78	142.95	127.23	125.19	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	0.01	0.03	0.28	0.67	0.80	..
Electricity	1.40	9.06	18.02	33.86	56.25	58.78	..
Heat	-	-	-	-	-	-	..
Shares in other (%)							
Coal	*5.5*	*6.8*	*4.3*	*5.3*	*4.9*	*4.9*	..
Peat	-	-	-	-	-	-	..
Oil	*5.3*	*10.9*	*15.9*	*15.9*	*17.3*	*18.0*	..
Natural gas	-	*0.1*	*0.2*	*0.5*	*0.7*	*0.8*	..
Biofuels and waste[1]	*87.7*	*75.9*	*69.1*	*63.1*	*53.3*	*51.7*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	*0.0*	*0.0*	*0.1*	*0.3*	*0.3*	..
Electricity	*1.5*	*6.4*	*10.5*	*15.0*	*23.5*	*24.3*	..
Heat	-	-	-	-	-	-	..

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p**
ELECTRICITY GENERATION[7]							
Input (Mtoe)	13.33	64.60	133.07	238.80	324.29	338.77	..
Output (Mtoe)	6.26	25.17	48.99	84.41	125.33	131.77	..
Output (TWh)	72.80	292.73	569.69	981.52	1457.32	1532.23	..
Output shares (%)							
Coal	*49.4*	*65.5*	*68.5*	*67.0*	*74.2*	*74.0*	..
Peat	-	-	-	-	-	-	..
Oil	*7.0*	*4.5*	*5.1*	*2.5*	*1.6*	*1.6*	..
Natural gas	*0.5*	*3.4*	*9.8*	*11.5*	*4.8*	*4.6*	..
Biofuels and waste [1]	-	-	*0.2*	*1.5*	*3.0*	*3.0*	..
Nuclear	*3.3*	*2.1*	*3.0*	*2.7*	*2.6*	*2.5*	..
Hydro	*39.8*	*24.5*	*13.1*	*12.7*	*9.5*	*9.3*	..
Wind	-	-	*0.3*	*2.0*	*3.1*	*3.3*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	-	*1.3*	*1.7*	..
TOTAL LOSSES	**15.60**	**59.63**	**124.25**	**207.06**	**267.13**	**275.06**	**..**
of which:							
Electricity and heat generation[8]	7.07	39.43	84.09	154.40	198.99	207.02	..
Other transformation	4.88	7.31	10.29	17.28	21.86	22.86	..
Own use and transmission/distribution losses	3.65	12.89	29.87	35.38	46.29	45.18	..
Statistical differences	**0.81**	**3.23**	**2.59**	**9.23**	**16.31**	**15.65**	**..**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p**
GDP (billion 2010 USD)	211.00	466.53	802.76	1656.62	2466.18	2630.95	..
Population (millions)	593.06	870.13	1053.05	1230.98	1324.17	1339.18	..
TPES/GDP (toe/1000 USD)[9]	0.76	0.66	0.55	0.42	0.35	0.34	..
Energy production/TPES	0.90	0.92	0.80	0.72	0.65	0.63	..
Per capita TPES (toe/capita)	0.27	0.35	0.42	0.57	0.64	0.66	..
Oil supply/GDP (toe/1000 USD)[9]	0.12	0.13	0.14	0.10	0.09	0.08	..
TFC/GDP (toe/1000 USD)[9]	0.68	0.52	0.39	0.29	0.23	0.22	..
Per capita TFC (toe/capita)	0.24	0.28	0.30	0.39	0.43	0.44	..
CO_2 emissions from fuel combustion ($MtCO_2$)[10]	188.1	529.1	885.1	1583.4	2057.7	2161.6	-
CO_2 emissions from bunkers ($MtCO_2$)[10]	2.5	5.1	7.2	14.0	16.4	17.1	-
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-15**	**15-16**	**16-17**	**17-18**
TPES	3.9	3.7	4.7	3.6	2.1	3.4	..
Coal	6.6	4.6	6.7	6.2	-1.3	5.0	4.7
Peat	-	-	-	-	-	-	..
Oil	5.6	6.2	3.8	5.0	5.0	3.0	..
Natural gas	18.0	8.1	9.0	-3.7	6.3	6.3	4.6
Biofuels and waste[1]	1.7	1.1	2.2	-0.6	4.4	-0.5	..
Nuclear	5.7	10.7	4.5	7.3	1.3	1.1	..
Hydro	5.5	0.4	5.3	1.8	0.9	2.9	..
Wind	-	47.4	27.8	16.2	7.4	14.1	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	16.2	23.7	38.8	48.9	33.0	..
TFC	3.1	2.6	4.4	2.7	2.7	3.8	..
Electricity consumption	8.3	5.8	6.8	7.3	7.0	5.1	..
Energy production	4.0	2.3	3.7	1.3	2.4	0.6	..
Net oil imports	2.6	11.3	4.8	6.8	7.0	2.8	..
GDP	4.8	5.6	7.5	6.8	7.1	6.7	..
TPES/GDP	-0.8	-1.7	-2.6	-3.0	-4.7	-3.1	..
TFC/GDP	-1.6	-2.8	-2.9	-3.8	-4.1	-2.7	..

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Footnotes to energy balances and key statistical data

1. Biofuels and waste comprise solid biofuels, liquid biofuels, biogases and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
2. In addition to coal, oil, natural gas and electricity, total net imports also include biofuels.
3. Excludes international marine bunkers and international aviation bunkers.
4. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
5. Industry includes non-energy use.
6. Other includes residential, commercial and public services, agriculture/forestry, fishing and other non-specified.
7. Inputs to electricity generation include inputs to electricity plants. Output refers only to electricity generation.
8. Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for nuclear and 100% for hydro, wind and solar photovoltaic.
9. Toe per thousand US dollars at 2010 prices and exchange rates.
10. "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach methodology from the *2006 IPCC Guidelines.* Emissions from international marine and aviation bunkers are not included in national totals.

ANNEX C: Acronyms, abbreviations and units of measure

In this report, abbreviations and acronyms are substituted for a number of terms that are frequently used in the International Energy Agency or in the Government of India. While these terms generally have been written out on first mention, this annex provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

ABT	availability-based tariff
AC	alternating current
ACS	average cost of supply
ADNOC	Abu Dhabi National Oil Company
AGC	automatic generation control
APM	Administered Price Mechanism
ARR	average revenue realised
AT&C	average technical and commercial
avg.	average
BEE	Bureau of Energy Efficiency
BHEL	Bharat Heavy Electricals Limited
BIRAC	Biotechnology Industry Research Assistance Council
BPL	below the poverty line
BS	Bharat Stage
BWR	boiling water reactor
CCEA	Cabinet Committee on Economic Affairs
CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
CEA	Central Electricity Authority
CEIIC	Clean Energy International Incubation Centre
CERC	Central Energy Regulatory Commission
CFL	compact fluorescent lamp
CIL	Coal India Limited
CNG	compressed natural gas
CO_2	carbon dioxide
COP	Conference of the Parties
CPCB	Central Pollution Control Board
CSIR	Council of Scientific and Industrial Research
CST	concentrated solar thermal
CV	calorific value
DAE	Department of Atomic Energy
DAM	day-ahead market

DBT	Department of Biotechnology
DC	designated consumer
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DEEP	Discovery of Efficient Energy Price
DGH	Directorate General of Hydrocarbons-
DISCOM	power distribution company
DPE	Department of Public Enterprises
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
ECBC	Energy Conservation Building Code
EEFP	Energy Efficiency Financing Platform
EESL	Energy Efficiency Services Limited
EfW	energy-from-waste
EPAR	Environment Protection Amendment Rules
EPCA	Environmental Pollution Control Authority
ESCerts	Energy Saving Certificates
EV	electric vehicle
E&P	exploration and production
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FBR	fast breeder reactor
FEEED	Framework for Energy Efficient Economic Development
FoR	Forum of Regulators
FSA	fuel supply agreement
FSRU	floating storage and regasification unit
GCF	Green Climate Fund
GDP	gross domestic product
GHG	greenhouse gas
GoI	Government of India
GST	Goods and Services Tax
G20	Group of Twenty
HDV	heavy-duty vehicle
HELP	Hydrocarbon Exploration and Licensing Policy-
HPO	hydro purchase obligation
HVDC	high-voltage direct current
IC	Innovation Challenge
ICAP	Indian Cooling Action Plan
IEA	International Energy Agency
IIT	Pan-Indian Institute of Technology
INDC	Intended Nationally Determined Contribution

IOCL	Indian Oil Corporation Limited
IPDS	Integrated Power Development Scheme
IPP	independent power producer
IREDA	Indian Renewable Energy Development Agency
ISPRL	Indian Strategic Petroleum Reserves
JODI	Joint Organisations Data Initiative
LDV	light-duty vehicle
LED	light-emitting diode
LNG	liquefied natural gas-
LPG	liquefied petroleum gas
MI	Mission Innovation
MNRE	Ministry of New and Renewable Energy
MoC	Ministry of Coal
MoEFCC	Ministry of Environment, Forests and Climate Change
MoES	Ministry of Earth Sciences
MoHI	Ministry of Heavy Industries
MoP	Ministry of Power
MoPNG	Ministry of Petroleum and Natural Gas-
MoSPI	Ministry of Statistics and Programme Implementation
MoST	Ministry of Science and Technology
MSD	micro solar dome
MSME	micro, small and medium-sized enterprise
MTEE	Market Transformation for Energy Efficiency
NAPCC	National Action Plan on Climate Change
NAMA	Nationally Appropriate Mitigation Action
NBIRT	NB Institute of Rural Technology
NCEEF	National Clean Energy and Environment Fund
NDC	Nationally Determined Contribution
NEAA	National Environmental Appellate Authority
NELP	New Exploration Licensing Policy
NEMMP	National Electric Mobility Mission Plan
NEP	National Energy Policy
NETRA	NTPC Energy Technology Research Alliance
NGT	National Green Tribunal
NLDC	National Load Despatch Centre
NHPC	National Hydroelectric Power Corporation
NO_x	nitrogen oxides
NPCIL	Nuclear Power Corporation of India Limited

NPS	New Policies Scenario
NPS-SDS	New Policies Scenario-Sustainable Development Scenario
NTPC	National Thermal Power Corporation
OALP	Open Acreage Licensing Policy-
OIDB	Oil Industry Development Board-
OIL	Oil India Limited-
OMC	oil marketing company
ONGC	Oil and Natural Gas Corporation-
PAHAL	Pratyaksh Hanstantrit Labh
PAT	Perform Achieve and Trade
PHWR	pressurised heavy water reactor
PM	particulate matter
PMCCC	Prime Minister's Council on Climate Change
PM-STIAC	Science, Technology and Innovation Advisory Council
PMUY	Pradhan Mantri Ujjwala Yojana
PNGRB	Petroleum and Natural Gas Regulatory Board-
POSOCO	Power System Operation Corporation
Powergrid	Power Grid Corporation of India Limited
PPA	power purchase agreement
PPAC	Petroleum Planning and Analysis Cell
PPP	purchasing power parity
PRGFEE	Partial Risk Guarantee Fund for Energy Efficiency
PSH	pumped storage hydro
PSC	production-sharing contracts
PSU	public-sector undertaking
PV	photovoltaic
PWR	pressurised water reactor
RBI	Reserve Bank of India
RD&D	research, development and demonstration
REC	renewable electricity certificate
REMC	Renewable Energy Management Centre
RLDC	Regional Load Despatch Centre
RPO	renewable purchase obligation
R&D	research and development
SDG	Sustainable Development Goal
SECF	State Energy Conservation Funds
SECI	Solar Energy Corporation of India
SEED	Science for Equity, Empowerment and Development
SEEP	Super-Efficient Equipment Programme

SERC	State Electricity Regulatory Commission
SHAKTI	Scheme for Harnessing and Allocating Koyala (coal) Transparently in India
SLDC	State Load Dispatch Centre
SME	small and medium-sized enterprise
SO_2	sulphur dioxide
SO_X	sulphur oxides
TCP	Technology Collaboration Programme
TFC	total final consumption-
TOD	time-of-day
TPES	total primary energy supply-
UDAY	Ujwal DISCOM Assurance Yojana
UJALA	Unnati Jyoti by Affordable LEDs for ALL
USD	US dollar
VAT	value-added tax
VCFEE	Venture Capital Fund for Energy Efficiency
VRE	variable renewable energy
ZED	Zero Defect and Zero Effect

Units of measure

bcm	billion cubic metres
EJ	exajoule
gCO_2/km	grammes of CO_2 per kilometre
gCO_2/kWh	grammes of CO_2 per kilowatt hour
Gt	gigatonne
Gt CO_2	gigatonnes of CO_2
Gt CO_2-eq	gigatonnes of CO_2 equivalent
GW	gigawatt
GWh	gigawatt hour
Hz	hertz
kb/d	thousand barrels per day
kcal/kg	kilocalories per kilogram
kg	kilogramme
kg CO_2	kilogramme of CO_2
km	kilometre
km^2	square kilometre
kt	thousand tonnes
kV	kilovolt
kWh	kilowatt hour
Lge/100 km	litres of gasoline equivalent per 100 kilometres
mb	million barrels

mb/d	million barrels per day
mcm/d	million cubic metres per day
mg	milligramme
mg/Nm^3	milligrammes per normal cubic metre
Mt	million tonnes
Mt CO_2	million tonnes of CO_2
Mt CO_2-eq	million tonnes of CO_2 equivalent
Mtoe	million tonnes of oil equivalent
Mtpa	million tonnes per annum
MVA	megavolt ampere
MW	megawatt
MWh	megawatt hour
m^3	cubic metre
μg	microgramme
t	tonne
t CO_2	tonne of CO_2
toe	tonne of oil equivalent
TWh	terawatt hour

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