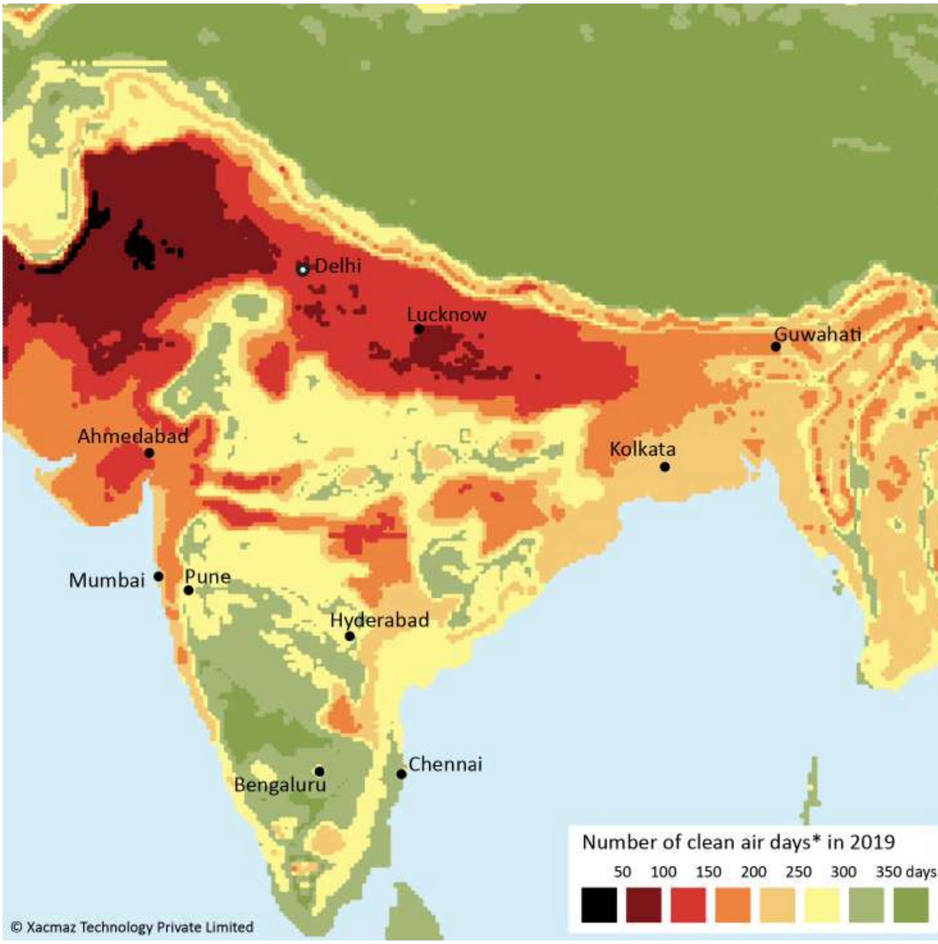
total of 124 cities may be an underestimate because not all of India's nearly 500 cities have air quality monitoring stations.

Figure 1.20 ▷ Number of clean air days in India, 2019



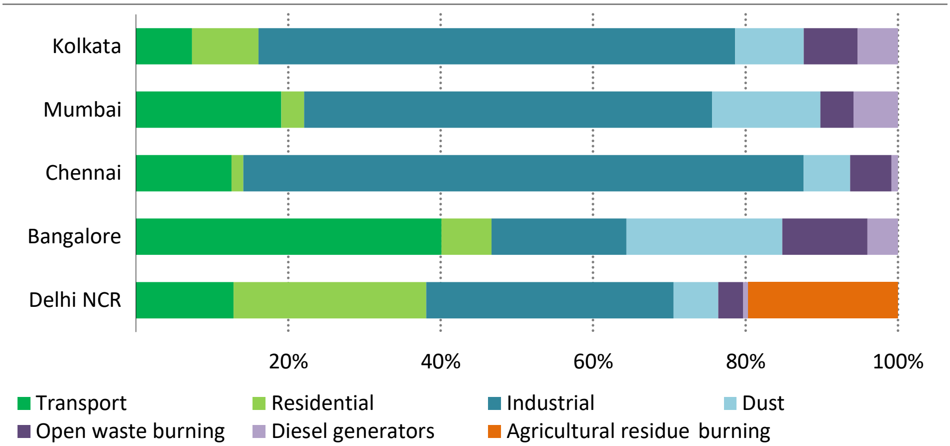
Nearly half of India's population lives in regions with fewer than 200 clean air days a year.

Notes: Clean air days are defined as days where the 24-hour average of fine particulate matter ($PM_{2.5}$) was lower than the CPCB safe limit of 60 microgrammes per cubic metre. This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: Blue Sky Analytics (2020).

While air pollution in India is perennial and affects all parts of the country, northern states suffer with particular acuteness in winter, and this contributes to making northern India one of the world's most polluted regions (Figure 1.20). The high levels of air pollution in northern India in the winter have much to do with the region's geographical and meteorological conditions, but the source of this pollution is anthropogenic, and stems primarily from the use of energy. From 70 to 90% of the particulate matter emissions in India's five largest urban agglomerations are a result of energy use (Figure 1.21).

Figure 1.21 ▷ Sectoral origin of $PM_{2.5}$ emissions in selected urban agglomerations



Energy consumption accounts for the majority of air pollutants in India's largest cities.

Notes: NCR = National Capital Region. Industrial emissions includes power generation; data for Bangalore and Chennai are from 2015, while the data of Kolkata, Mumbai and Delhi NCR are from 2018; the NCR includes the cities of Delhi, Noida, Ghaziabad, Gurgaon, Faridabad and other districts that are a part of the geographic entity of NCR; all urban agglomerations considered include some non-urban areas that are a part of the surrounding areas.

Source: IEA analysis based on UrbanEmissions.info (2020) and TERI (2018).

The contribution of human activity to air quality was illustrated during India's Covid-19 related lockdowns, which brought a halt to almost all economic activity. During the six-week lockdown that started in late March, $PM_{2.5}$ levels were 58% lower in Delhi, 45% lower in Bangalore and 30% lower in Chennai than in the same period in the previous year. Similar steep drops were observed in various Indian cities and for all key air pollutants including sulphur dioxide, nitrous oxides and carbon monoxide (Navinya, Patidar, & Phuleria, 2020). These improvements were short-lived, however, and air quality deteriorated quickly as restrictions linked to the pandemic were eased.

The sources of pollutants vary depending on the region and time of the year. The largest contributors across regions tend to be transport, industry, power generation, and biomass or waste burning. One key trigger of rapidly deteriorating air quality in northern India every year is agricultural residue burning in October and November, although transport, industry and other energy sector sources continue to account for a large share of emissions even at this time of the year.

While the focus of research, monitoring and action has largely been on urban areas, air quality levels are also very poor in rural India, where ambient air pollution is compounded by poor household air quality due to the traditional use of biomass for cooking. The overall result is that air pollution has emerged as one of India's deadliest killers and therefore a major public health issue.

The Government of India responded by launching the National Clean Air Programme (NCAP) in 2019, with a target to reduce $PM_{2.5}$ and coarse particulate matter (PM_{10}) concentrations by 20-30% by 2024 from 2017 levels. While such a reduction will not necessarily ensure that cities meet the standards under NAAQS, this is the first time that an air quality improvement target has been linked to a specific date for delivery.

Meeting the target by the date set in the NCAP is likely to be challenging, not least because it will depend on changes in sectors that are not within the remit of the Ministry of Environment, Forests and Climate Change, which is the ministry with responsibility for the NCAP. The changes required are likely to need to include electrification and modal shifts in transport, the universal adoption of clean cooking fuels, a more consistent and stable supply of electricity along with higher levels of renewables generation, and action on industrial emissions through greater energy efficiency and the use of alternative sources of energy to reduce pollution. In northern India, where agricultural residue burning is a key contributor to air pollution in the winter, there is an opportunity to expand the use of agricultural residues in the (currently small-scale) production of bio-based fuels and electricity.

Land

Historically, the primary land challenges relating to energy in India arose from hydropower projects. Despite much of this hydropower capacity being added many years ago, a number of difficult legacy issues remain, including the resettlement and rehabilitation of populations that were displaced during the construction of dams. More recently, India’s push for utility-scale solar has also thrown up challenges around land procurement and use. The National Institute of Solar Energy has estimated that 750 GW of solar PV would need only 3% of India’s wasteland areas (TERI, 2017). However, wasteland areas have declined over the past few decades, and such wasteland may not always be ideally located for solar projects. In those cases where agricultural land is to be procured for solar projects, the approval of such land for non-agricultural uses can be a time-consuming and contentious process. Land is a state-level responsibility in India, meaning that approvals are needed from the relevant departments of state governments, and from village-level administrations. Improperly maintained land records can lead to patches of land being claimed by multiple entities, and this can slow down land acquisition or lead to litigation.

There are other obstacles too. In some states, there are land ceiling limits which restrict the amount of land that individual owners can acquire. The high population density in most parts of the country, and the tendency of land holdings to be fragmented, compound the difficulties. The average farmland holding was 1 hectare in 2015 (Business Standard, 2018). With the Solar Energy Corporation of India (SECI) stating a minimum land requirement of

1.5 hectares per megawatt, this implies that developers have to deal with multiple landowners.

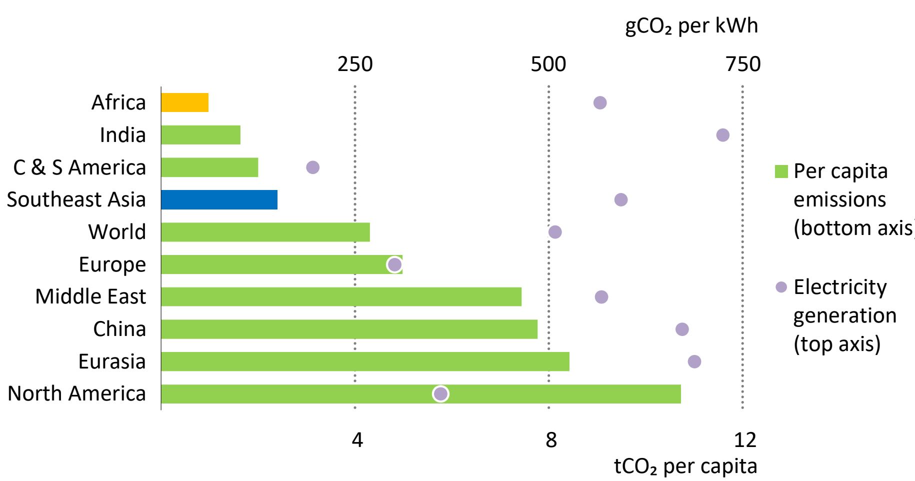
Measures have been introduced to overcome these problems and facilitate the acquisition of land for the development of solar capacity. The SECI has been developing solar parks with state governments, and in these cases the issue of land acquisition is handled by the government. Single-window clearances have also been set up in a few states to expedite approvals. Nonetheless, the lack of a transparent and uniform land acquisition policy, combined with the multiplicity of approvals required, means that land acquisition continues to be a problematic issue for many developers.

Carbon dioxide emissions

Per capita emissions in India remain low by international standards, but 14% of global energy-sector emissions growth since 1990 has nonetheless come from India. India's energy-sector related CO_2 emissions have more than quadrupled since 1990, with the major sources of emissions growth being power generation, industry and transport.

Emissions growth from power generation over this period has been nearly twice total emissions from all sectors in 1990. Coal meets 45% of India's primary energy demand, but is responsible for 70% of India's energy sector CO_2 emissions. The carbon intensity of India's power sector is 725 grammes of CO_2 per kilowatt-hour (g CO_2/kWh), compared with a global average of 510 g CO_2/kWh, underlining the predominant role of inefficient coal-fired generation (Figure 1.22).

Figure 1.22 ▷ CO_2 emissions per capita and emissions intensity of electricity generation by region, 2020



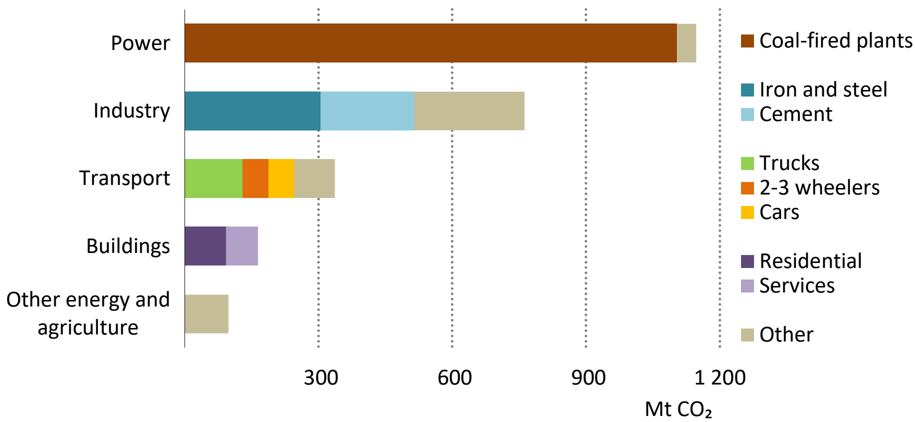
India's per capita CO_2 emissions are 60% lower than the global average, but the emissions intensity of its electricity generation is among the highest of any country.

Notes: tCO_2 = tonnes of carbon dioxide; C&S America = Central and South America.

After power generation, the next highest emitting sector is industry (Figure 1.23). India provides just over 6% of steel production globally, and the iron and steel sector is the largest industrial subsector in terms of emissions: it is responsible for around 30% of India's industrial energy consumption. Coal provides around 85% of the energy used for iron and steel, and the sector makes relatively little use of recycled scrap. This means that India's steel industry is more emissions-intensive than its counterparts in many other countries.

India provides around 8% of global cement production, and this is the second-largest emitting industrial subsector. Although coal and oil are the main fuels used to provide heat for its cement industry, a number of energy efficiency measures have been introduced at Indian cement plants, and total emissions (including indirect emissions from the use of electricity) per tonne of production are nearly 15% lower in India than in China.

Figure 1.23 ▷ CO_2 emissions from the Indian energy sector, 2019



India's power sector is the largest contributor to its CO_2 emissions, and coal-fired power plants are responsible for the great majority of power sector emissions.

Note: *Other* includes other energy sector and agriculture

Oil demand for road freight transport in India has tripled since 2000, highest after China. More than 45% of emissions from road transport in India come from trucks. India's heavy-freight trucks have a relatively high level of fuel consumption per tonne kilometre compared with other countries, but the implementation of new engine standards in 2020 should help to reduce the emissions intensity of activity in the future.

Emissions from passenger road transport in India have also quadrupled since 2000. India has a high share of two- and three-wheelers in its vehicle fleet (four-fold of passenger cars), and this helps to explain why passenger cars in India accounts for only 18% of its overall transport emissions (merely 36% even if two- and three-wheelers is added). This is much lower than many other countries; in the United States, for example, passenger cars account for 57% of total transport emissions.

The direct use of fossil fuels in the buildings sector resulted in just over 160 Mt of CO_2 emissions in 2019, with a further 460 Mt of indirect emissions coming from the use of electricity. India has been seeking to improve the energy efficiency of its buildings through mandatory building energy codes and voluntary rating schemes, as well as through programmes to improve the efficiency of appliances and equipment.

Water

With just 4% of the world's water resources but 18% of its population, India counts as one of the world's most water-stressed countries. Around 45% of its population faces acute water shortages. Groundwater, which provides 85% of the country's rural drinking water and about 60% of its irrigation water, is being rapidly depleted (Kim, 2018). A third of India's groundwater reserves are currently overexploited, meaning more is pumped out than is naturally recharged by rainfall. Moreover, almost 70% of India's water is contaminated (NITI Aayog, 2018). India also suffers frequently from natural disasters: between 1996 and 2015, 19 million people a year in India were impacted by flooding and 17.5 million people a year were affected by drought (UN Water, 2019).

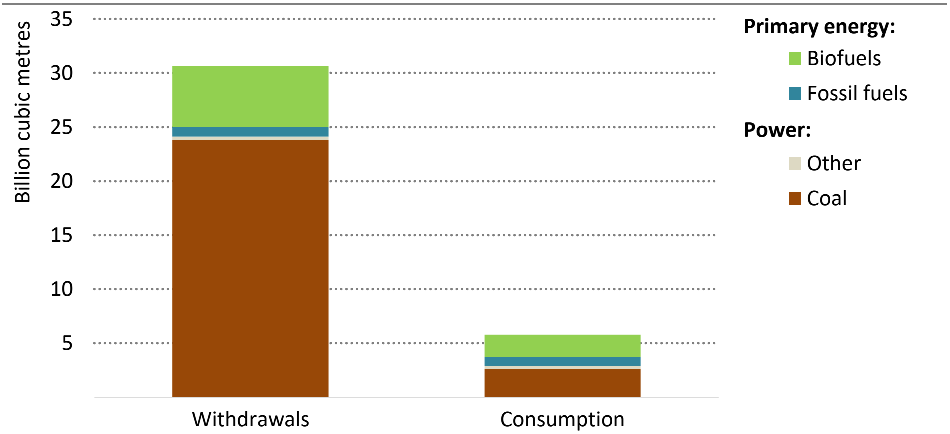
Agriculture accounts for 80% of India's water demand. Water-intensive rice, sugar, maize and cotton are the most prevalent crops grown, and their export means that India is effectively the world's biggest water exporter. Agriculture in India is significantly dependent on irrigation, with over 30% of its agriculture relying on it. A legal framework allowing farmers to extract as much water as they want from underneath their land has contributed to the rapid decline of India's groundwater resources. To improve agricultural productivity and boost incomes, India has undertaken an aggressive campaign to deploy almost 3 million solar pumps. Up to 2018, roughly 180 000 had been deployed. This initiative does not, however, help to tackle the problem of declining groundwater resources, and may exacerbate it.

The problems have been made worse by inefficient irrigation practices, such as flood irrigation. On average, targeted irrigation is deployed on just 10% of irrigated areas across states. The upshot is that water use efficiency on farms in India is among the lowest in the world: three to five times more water is used than on farms in China or the United States to produce the same amount of crops (NITI Aayog, 2018). Switching from low- to high-water-saving irrigation practices could save up to 47% of irrigation water by 2030 (Vaibhav, 2020).

Today, the energy sector withdraws roughly 30 bcm of water (the volume of water removed from a source) and consumes almost 6 bcm (the amount withdrawn but not returned to a source) (Figure 1.24). Coal-fired power generation accounts for 80% of the water withdrawals made by the energy sector, with the water being used mainly for cooling and ash disposal. The energy sector accounts for less than 5% of India's total water withdrawals and less than 2% of consumption, but water availability is nonetheless essential for India's energy security.

India's thermal power plants are already being impacted by water stress: droughts and water shortages caused India to lose 14 TWh of thermal power generation in 2016 (Luo, Krishnan, & Sen, 2018). Recognising the risks posed by potential future water shortages, the government introduced a requirement for new and existing thermal power plants to switch to cooling towers (which withdraw less water than once-through systems) and to comply with water consumption limits per megawatt-hour. Compliance is self-reported, however, and a recent study found that only half of thermal plants for which data could be obtained were compliant with the rules (Manthan Adhyayan Kendra, 2019).

Figure 1.24 ▷ Water use in India's energy sector by fuel and power generation type, 2019



Coal-fired power generation accounts for 80% of India's energy sector water withdrawals.

India has made significant progress towards providing access to clean drinking water and sanitation for all (UN SDG 6). Over 90% of the population now has access to a basic water service.[4] However, more work remains to be done: nearly 200 000 Indians die each year from a lack of access to safe drinking water, 60% of India's wastewater is released untreated, and 40% of the water supply is lost to leaks or theft (Kim, 2018; NITI Aayog, 2018), while 40% of India's population does not have an improved drinking water source available.

For those who do not have access to water, its collection is often done by women, who obtain it from tankers in urban areas or by walking on average 5 km to 20 km a day to a source of water in rural areas (Chandran, 2018). For those who do have access to water, the quality can be poor and intermittent. In many cities, supply is available for just two to three hours a day on average (Chattopadhyay, S., 2020). The government has pledged to provide access to safe and adequate drinking water to all by 2022 and a piped water connection to each household by 2024 via the Jal Jeevan Mission.

Increasing water demand, declining per capita water availability, problems with water quality, lack of storage options, and changing patterns of use all mean that water will remain

[4] A basic water service is access to an improved drinking water source that can be collected in 30 minutes or less round trip. Safely managed drinking water services, the set target under SDG 6.1, are defined as use of an improved drinking water source which is accessible on premises, available when needed and free from contamination.

a challenge for India in the years to come. On current trends, it is estimated that half of India's water demand will be unmet by 2030 (NITI Aayog, 2018). The government of India established the Ministry of Jal Shakti in May 2019, which seeks to prioritise water needs and co-ordinate policies and actions affecting water and water-related activities. Given the importance of water for its energy future, it will be necessary to assess the existing and potential future water needs of the energy sector in order to avoid potential choke points and to identify synergies where they exist.

Several synergies emerge when the SDGs are viewed through an integrated lens, especially between SDG 6 (water and sanitation for all) and SDG 7 (energy for all). For example, technologies being deployed to provide access to electricity can also help with the provision of clean drinking water through the use of pumps and filtration systems. Approaching water and electricity access in an integrated way may shift the emphasis from off-grid solutions towards mini-grid or grid-connected solutions, especially if productive uses are considered, for example the use of water and electricity in agriculture. Managing the energy-water-food nexus is going to be essential in the effort to reach development and climate goals.

1.4 Which way from here?

The projections in this *Outlook*, described in detail in the chapters that follow, describe possible pathways for the future of Indian and global energy systems. They largely follow the overall scenario structure in the IEA *World Energy Outlook 2020*, but there is also an additional case that is specific to this report. The main variable that differentiates the various pathways is the way that government policy preferences and implementation evolve over the coming decades, but our analysis also allows us to explore the implications of a rapid recovery from the Covid-19 crisis, as well as a pathway in which a prolonged pandemic has longer-lasting effects on India's economic development.

- The **Stated Policies Scenario** (STEPS) assumes that significant risks to public health are brought under control gradually over the course of 2021, allowing for a steady recovery in economic activity. This scenario incorporates our assessment of all the policy ambitions and targets that have been legislated for or announced by the Indian government and by other governments around the world. These include nationally determined contributions (NDCs) under the Paris Agreement. An overview of the policy aims incorporated into the STEPS is included in the next section. It is important to note, especially in the light of the IVC, that broad energy and environmental policy objectives are not automatically assumed to be met in the STEPS. They are implemented to the extent that, in our assessment, they are backed up by specific measures and funding. This is not a judgement of the feasibility of the government's ambitions or its commitment to them, but a reflection of our view of the real-life constraints – including regulatory, financial and administrative barriers – that have to be faced.
- The **India Vision Case** (IVC) takes a more optimistic view of the prospects for full implementation of India's stated policy aims (Box 1.3). On the economic front, the IVC implies not just a rapid resolution to the public health crisis caused by Covid-19, but also successful structural reforms that raise the long-term growth potential of India's

economy, meaning that the assumed rate of economic growth is higher than in the STEPS. In the energy sector, it assumes that key targets are met to the extent possible. One important finding from this analysis is that it is not possible to hit every target; for instance, the government's volumetric target to expand domestic coal production is not met in the IVC partly because of the expansion of renewables and improvements in efficiency in line with other government targets. The IVC in this year's edition follows a similar case included in the 2015 *India Energy Outlook*, allowing us to explore how India's vision has evolved over the last five years.

- By contrast, the **Delayed Recovery Scenario** (DRS) examines downside risks to economic and social development, linked to the possibility that the Covid-19 pandemic turns out to be more prolonged than assumed in other scenarios. The overarching policy assumptions are similar to those in the STEPS, but the assumed rate of economic growth is lower. The global outcomes in this scenario are explored in full in *World Energy Outlook 2020*; insights into the implications for India are introduced at various points in the chapters that follow.
- The **Sustainable Development Scenario** (SDS) takes a different approach from the other scenarios and cases in this *Outlook*. Whereas the others take a set of initial assumptions and see where they lead, the SDS works back from the achievement of specific outcomes and assesses what combination of actions would be required to get there. The key outcomes that this scenario delivers are drawn from the UN SDGs: effective action to combat climate change by holding the rise in global average temperature to "well below 2°C … and pursuing efforts to limit [it] to 1.5°C", as set out in the Paris Agreement; universal access to affordable, reliable and modern energy services by 2030; and a substantial reduction in air pollution. In the SDS, India is on track to reach net zero emissions beyond the modelling horizon – in the mid-2060s.

None of these scenarios is a forecast of what will happen over the coming years; the IEA does not have a single view of how the future will look. With myriad near-term uncertainties, our aim is more modest and, we hope, more useful: to highlight the range of possible futures, and the actions and circumstances that might bring them about.

The projections in each of these scenarios are generated by the IEA World Energy Model, an energy systems model that has been developed over many years to provide insights into energy and environmental trends. A key asset of this integrated modelling is that it allows us to investigate the interconnections among different parts of the system, both within India and between India and the rest of the energy world. This generates insights into the trade-offs and co-benefits that exist between different policy objectives and courses of action.

India faces the need to pursue multiple policy objectives in parallel in order to support a growing population and economy, including energy access, energy security and sustainability. In order to do so effectively, there is a need to approach energy policy making and planning with a view to the system-wide impacts of different policy choices. For example, road or rail transport policies formulated by the respective ministries in India have potential implications not only for transport demand, but also for power generation capacity, refinery configurations, natural gas supply infrastructure, GHG emissions and air quality. And India's choices also have significant impacts for global trends. The scenarios and analysis in this *Outlook* allow us to highlight these interlinkages.

Box 1.3 ▹ How is the India Vision Case different?

The IVC reflects the energy, environment and economic targets of the Indian government. It goes beyond stated policies and tests the following aspirations against the outcomes of *WEO* modelling:

- Achievement of 450 GW of non-hydro renewable capacity by 2030. A greater degree of financial de-risking, underpinned by a favourable regulatory environment, allows public and private actors to scale up investment in clean energy technologies. Compared with the STEPS, there is much greater uptake of rooftop solar and wind energy.
- A substantial increase in the share of natural gas in India's primary energy mix by 2030. There is a much greater use of gas for electricity generation than in the STEPS, and gas is used in particular as a source of flexibility. Gas also displaces fuels including diesel in the captive power sector.
- An acceleration in the uptake of alternative fuels in the transport sector. The share of EVs in total road vehicle sales reaches 38% by 2030 (25% of sales in the case of passenger cars), and bioenergy, including both bioethanol/biodiesel as well as bio-CNG, start to be used.
- A rapid and widespread implementation of efficiency measures across the energy economy, especially in buildings but also in industry.
- Achievement of India's energy access goals in full by 2030, meaning that traditional uses of biomass are entirely phased out by this date.
- A longer-term focus on deep decarbonisation of the industrial sector, which translates into a ramp-up of carbon capture and storage technologies, together with early efforts to explore hydrogen pathways that yield some initial production from low-carbon sources.

1.4.1 India's energy policies

India's energy policies and ambitions are often disparate and sector-specific because they emanate from different ministries and agencies (Box 1.4). However, these policies and ambitions all relate to the overall goal of providing affordable, reliable and sustainable energy services.

India's NDC under the Paris Agreement is an important reference point for energy and climate policy. In the NDC, India has committed to improve the emissions intensity of its economy by 33-35% by 2030, compared with 2005 levels, and to achieve a 40% share of non-fossil fuels in electricity generation capacity by 2030. The prime minister of India has also articulated seven focus areas for its energy economy, including a move towards a "gas-based economy", cleaner use of fossil fuels, greater use of biofuels, rapid scaling up of renewables, a focus on electric mobility, a shift towards emerging fuels including hydrogen, and digital innovation across energy systems.

There are specific targets to be achieved by 2030, including 450 GW of renewable power capacity, a 15% share of natural gas in the primary energy mix, a 30% share of passenger car sales for EVs and a 20% blending of biofuels in petrol. There are also targets for increased energy efficiency across sectors, affordable housing for all, the electrification of railways, the reduction of crude oil imports, and the ending of coal imports in the 2020s. While they all come under the overarching framework described above, many of these targets were decided independently of one another.

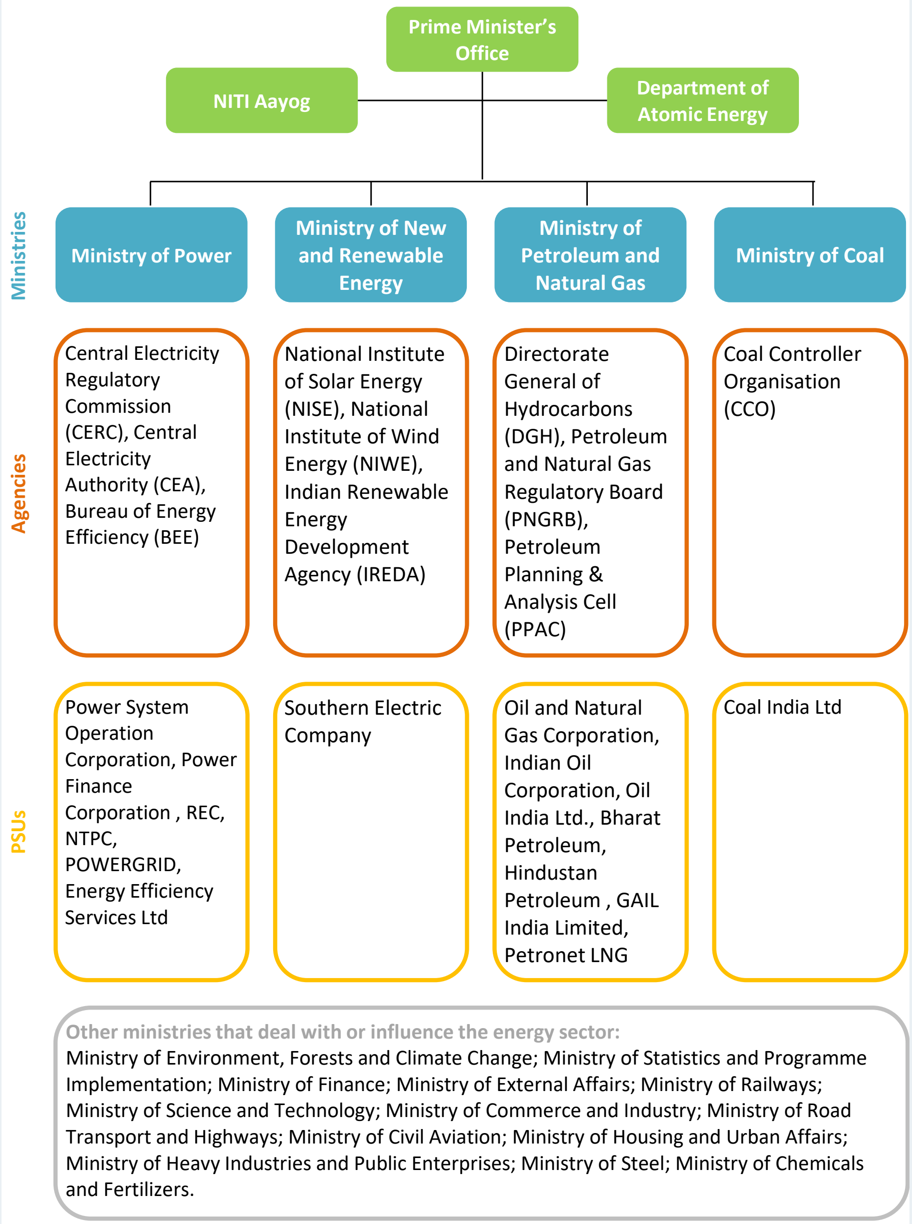
In addition to central government targets, there are subnational targets announced by state governments, especially in the case of electricity, EVs and energy efficiency. For instance, the state of Gujarat announced in 2019 that it will no longer invest in new coal-fired power capacity. Some states also have targets and policies on rooftop solar and electric mobility in their respective jurisdictions.

Box 1.4 ▹ India's energy governance and institutional arrangements

India's energy sector is subject to the central and state governments in different ways. Under India's constitution, the petroleum, natural gas, aviation and railways sectors come within the legislative ambit of the central government, whereas electricity comes within the legislative ambit of both the central and state governments. As a result, India's energy sector is governed by multiple ministries and agencies at both the central and state levels.

In the central government, various ministries and agencies have energy-related responsibilities under the overall purview of the Prime Minister's Office (PMO). Each of these in turn has under it a range of specialist agencies and regulatory bodies, as well as public sector undertakings (PSUs), which are publicly owned companies (Figure 1.25). There are also agencies under the 28 state governments with responsibilities related to electricity, road transport, buildings and energy efficiency; these include State Electricity Regulatory Commissions (SERCs) in charge of managing intra-state transmission, distribution, trade and other aspects of electricity supply. There is also a Forum of Regulators (FOR) to facilitate co-ordination among the multiple state regulatory agencies and the central regulator.

Figure 1.25 ▷ Governance of the energy sector by the central government



India has multiple bodies in central government with a range of energy-related competencies and functions.

1.4.2 *Economic and population growth*

1

Alongside energy policies, the other principal determinants of energy demand growth in our scenarios are the rates at which economic activity and population are assumed to grow. These indicators are naturally subject to a wide level of uncertainty, which has been exacerbated – particularly for the economy – by the effects of the Covid-19 pandemic. With this in mind, this *India Energy Outlook* considers multiple possible trajectories for future growth in India's GDP.

After an unprecedented drop of around 8% in economic output in 2020, uncertainties over employment and strains to balance sheets and household finances are feeding through into constrained investment, despite government attempts to stimulate activity and limit the economic damage (see section 1.3.1). Against this backdrop, the near-term shape of the economic recovery is closely tied to success in tackling the spread of the virus. However, the longer-term outlook also depends on building out India's physical and social infrastructure (a major focus for India's stimulus spending), as well as on progress in tackling structural challenges affecting investment such as complicated permitting processes, tax arrangements and land acquisition processes.

Table 1.2 ▷ Real GDP average growth assumptions by scenario

		STEPS			IVC	DRS
	2010-19	2019-25	2025-40	2019-40	2019-40	2019-40
India	6.6%	4.5%	5.7%	5.4%	6.0%	4.9%
World	3.4%	2.7%	3.1%	3.0%	3.1%	2.6%

Note: Calculated based on GDP expressed in year-2019 US dollars in PPP terms.

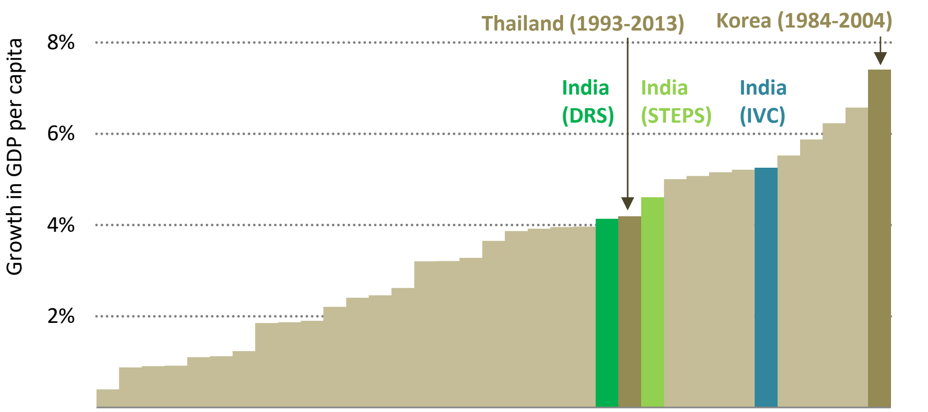
Sources: IEA analysis based on IMF (2020b); IMF (2020c); Oxford Economics (2020).

Our baseline assumption in the STEPS and in the SDS is that the pandemic is gradually brought under control in the course of 2021, allowing for a steady but far from V-shaped recovery in economic activity. In these scenarios, the supply side effects of the pandemic are significant, but are limited by the relatively short duration of the crisis together with effective policy responses, and the trend rate for growth in Indian GDP post-2022 moves back towards the level assumed before the crisis. The Indian economy is nonetheless smaller in 2040 than it was in the same scenarios in the *WEO 2019*.

In the IVC, a swift and effective recovery from the effects of Covid-19 is accompanied by a range of structural reforms that allow India to recover the lost ground in full and raise its long-term growth potential. In this case, India becomes a $5 trillion economy before the end of the decade, somewhat later than targeted by the Indian government. Conversely, the DRS illustrates the risks arising from a prolonged pandemic. In this scenario, unemployment and fragile finances hit demand and investment across the entire economy, and rising debts limit the scope and effectiveness of government action.

To put these growth trajectories in historical context, we looked at macroeconomic data since 1950 to see how other countries fared from the moment that they achieved a similar level of economic development to today's India, and compared the subsequent economic performance of those countries with the assumptions in our scenarios. Despite the shock of Covid-19, the assumed rates of growth in all our India scenarios are in the upper part of the historical range (Figure 1.26). The IVC is in the top 10% of the sample, and the only countries that have performed better than India does in the IVC are East Asian exporters such as Korea that saw sustained rates of rapid growth. In the STEPS and SDS, India's projected growth would come in slightly ahead of the post-1993 record of Thailand (a period that includes the effects of the Asian financial crisis).

Figure 1.26 ▷ India's economic outlook by scenario in a historical context



The GDP growth rate outlook considered in the IVC is in the top 10% of the sample of countries with similar levels of per capita income in the past.

Notes: Figure shows the average change in GDP per capita over a 20-year period for a sample of countries, starting when GDP per capita was comparable to India today. Data since 1950, excludes major hydrocarbon exporters.

Source: IEA analysis based on data from Penn World Tables (2020).

Our population assumptions for India are derived from the median variant of the United Nations projections (UNDESA, 2019). According to these estimates, India's population rises from 1.37 billion in 2019 to 1.59 billion in 2040, meaning that it becomes the most populous country in the world by the mid-2020s. India's total fertility rate in 2017 fell to 2.2, implying that every woman was giving birth to 2.2 children. Since then it is likely to have fallen close to the "replacement level" mark of 2.1 — and will continue to fall in the next two decades — thereby moderating the population growth to 2040. The share of India's population living in urban areas is currently around 34%, but this is assumed to rise to 46% by 2040, meaning that India's urban population is projected to rise by some 270 million people over the coming two decades. This is the equivalent of adding a new city the size of Los Angeles every year.

1.4.3 Energy prices[5]

The equilibrium prices for our scenarios (where comparable scenarios exist) have been revised down as a result of the pandemic, because of the effect of the crisis on global demand and because of changes to producer strategies and cost structures on the supply side. However, although the price trajectories are smooth, the possibility of price spikes and volatility cannot of course be discounted, and may indeed have increased as a result of very sharp cuts to investment and strains on producer finances.

In the case of oil, prices rise in the STEPS in order to stimulate a rebound in investment, after which they settle in a range between $75/barrel to $85/barrel, a level at which global supply – including from US shale – is quite elastic. Natural gas prices rise gradually as the current global surplus erodes: India's imports are increasingly assumed to be priced off indices that reflect Indian market dynamics rather than the cost of competing fuels. International coal prices remain subdued, reflecting lower global consumption as well as the ambition in India to satisfy a larger share of demand from domestic supply.

Table 1.3 ▷ India fossil fuel prices by scenario

			STEPS		IVC		SDS		DRS	
Real terms ($2019)	2010	2019	2025	2040	2025	2040	2025	2040	2025	2040
Crude oil ($/barrel)	91	63	71	85	71	85	57	53	59	72
Natural gas ($/MBtu)	9	11	10	9	9	9	5	6	9	9
Steam coal ($/tonne)	71	68	65	63	62	60	58	51	61	59

Notes: MBtu = million British thermal units. The crude oil price is a weighted average import price among IEA member countries. Natural gas prices are averages for imported gas, expressed on a gross calorific value basis. Steam coal prices are weighted averages adjusted to 6 000 kilocalories per kilogramme. The steam coal price is solely for imports. India prices for natural gas and steam coal are both wholesale prices.

Prices in the IVC are assumed to be broadly similar to those in the STEPS, as the changes in Indian demand are not in themselves large enough to affect global equilibrium prices. Natural gas could have been an exception to this, but the upward pressure on global prices created by extra Indian LNG imports in this scenario is assumed to be offset by the creation of a deeper and better functioning gas market, which in itself is sufficient to bring forward additional investments in supply.

Prices in the DRS are lower for each fuel than in the STEPS because demand is lower and it takes longer to work off the existing overhang in supply capacity. In the SDS, fuel prices stabilise at still lower levels because of considerably lower demand for fossil fuels, removing the need to develop higher-cost resources.

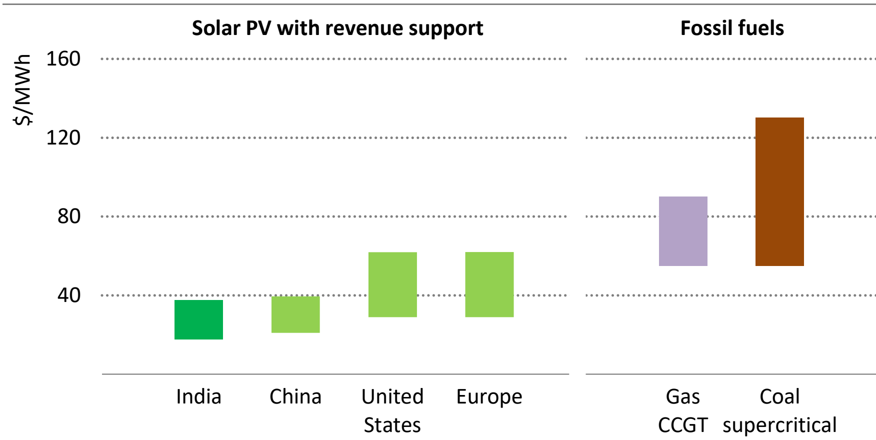
[5] See the *World Energy Outlook 2020* for additional details on the global price trajectories

1.4.4 Technology innovation, deployment and costs

A wide range of technologies are deployed to meet energy demand in our scenarios, and the cost of each of these is influenced in the World Energy Model by a continuous process of technology improvement and learning. This applies across the board to appliances and motors purchased by end users; infrastructure for transporting energy products, including smart grids; and technologies for electricity generation, energy extraction and transformation.

A crucial dynamic for the India outlook is the way that key renewable electricity production and storage technologies – including solar PV, wind and batteries – are expected to continue getting cheaper quickly through a combination of research, economies of scale and improvements in manufacturing and installation processes (Figure 1.27). The pace of change varies by scenario according to levels of deployment, linked in turn to the policies that are in place. However, with revenue support mechanisms in place that bring down financing costs in countries including India, new solar PV projects are now estimated to have levelised cost of electricity (LCOE) of $20 per megawatt-hour (MWh) to $40/MWh in India, entirely below the range of LCOE for new coal-fired power plants and approaching parity with the operating costs of some existing coal-fired plants. Coal-fired plants may be able to capture some additional market value because of their ability to match system needs, indicating a closer competition than one based solely on costs alone. But it remains the case that utility-scale solar PV is already very well placed as a preferred technology for new generation, and there are innovative ways in which solar is being bundled together with other technologies to increase its value (see section 3.2).

Figure 1.27 ▷ Utility-scale solar PV LCOE under revenue support mechanisms, 2020 final investment decision



Utility-scale solar PV is now consistently cheaper than new gas- or coal-fired power plants due to technology gains and revenue support mechanisms.

Note: CCGT = combined-cycle gas turbine.

Oil and gas costs around the world are structurally lower than in previous *WEO*s, although in many cases resources gradually become more expensive to extract over time (as continued upstream innovation and technology improvements are offset by the effects of depletion on costs). As a result, these fuels face increasingly stern competition in a growing number of applications from low-carbon energy supplies.

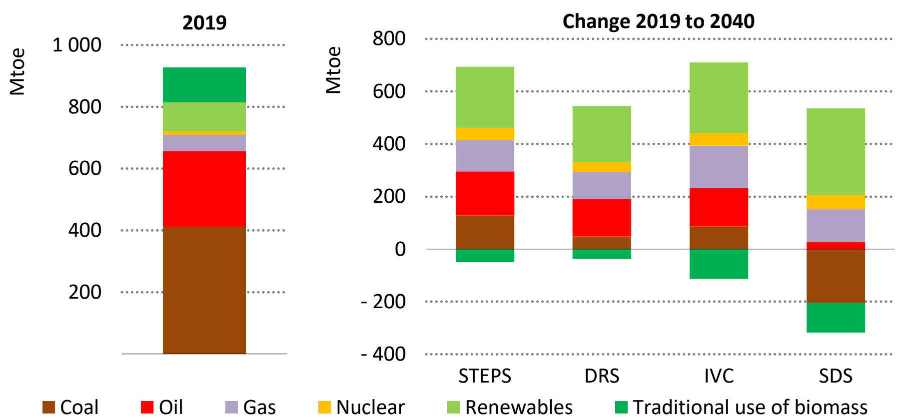
Urbanisation and industrialisation in India

Building an energy future

SUMMARY

- The Covid-19 pandemic has introduced major new uncertainties into the outlook for India's energy sector, but it has not altered the key underlying drivers. Chief among them are urbanisation and industrialisation. Up until now, India's economic growth has been driven mainly by the services sector, rather than the more energy-intensive industry sector, and the rate at which India has urbanised has been somewhat slower than in other emerging countries. How fast India urbanises and industrialises over the coming decades, and which policies govern these processes, will be of crucial significance for its energy future and for global trends.
- Over the period to 2040, an estimated 270 million people are likely to be added to India's urban population, the equivalent of adding a new city the size of Los Angeles every year. Even with such rapid urbanisation on a very large scale, the share of India's population living in urban areas in 2040 is still expected to be less than 50%.

Figure 2.1 ▷ Total primary energy demand in India by fuel and scenario



India leads global energy demand growth in every WEO scenario, although the way this demand is met depends on the interaction of policies, technologies and market forces.

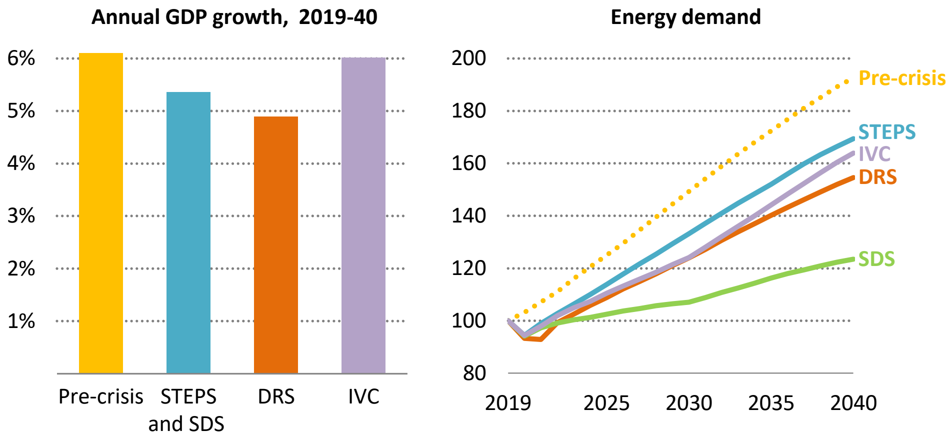
- Most of the buildings that will exist in India in 2040 have yet to be built. Urbanisation underpins a massive increase in total residential floor space from less than 20 billion square metres today to more than 50 billion in two decades' time. This prompts huge growth in demand for energy-intensive building materials. In the STEPS, demand for cement more than doubles to 2040, and demand for steel nearly triples.

- Urbanisation is also a spur for a transition in household energy use away from solid biomass and towards electricity. Rising ownership of appliances and demand for air conditioners mean that the share of energy demand taken by electricity in India's buildings sector rises from a quarter today to around half by 2040 in the STEPS. There is considerable scope for India to expand the application of its Energy Conservation Building Codes and further tighten appliance standards to limit future strains on its energy system.
- Transport is currently the fastest-growing end-use sector in terms of energy demand, and urbanisation will foster further growth. In many Indian cities, increasing demand for transport has so far led to much congestion and poor air quality. This has prompted a range of policy initiatives on fuel efficiency and quality, mass transit, and the electrification of transport. However, today's policy settings are not yet enough to avoid a large projected increase in oil demand for road transport, which doubles in the STEPS by 2040.
- Industry is the end-use sector that currently uses most energy, and its share in total final consumption rises from 36% today to 41% by 2040 in the STEPS. As coal use for power generation flattens out, industry accounts for almost two-thirds of the growth in India's coal demand and becomes the major source of growth in emissions. Moreover, since the majority of goods transported in India move by road, industrial expansion translates into rapid growth in diesel use for road freight, despite initiatives to shift more of the freight market onto the railways.
- Efforts to promote energy efficiency and material efficiency, and greater use of natural gas and electricity, in particular for lighter manufacturing, all mitigate the rise in industrial energy use in the STEPS, but there is considerable potential for further efficiency gains. These gains are seen to some extent in the IVC and more comprehensively in the SDS.
- Different scenarios inevitably produce different outcomes. In the DRS, energy demand and emissions are suppressed by a lower level of economic activity. Positive environmental outcomes therefore come at a very high cost. By contrast, the IVC delivers both higher economic growth and lower emissions than the STEPS as a result of policy actions which increase efficiency and achieve a faster transition to clean electricity and natural gas.
- The SDS goes further in the direction of improving efficiency and the use of low-carbon technologies. Alongside improved air quality and enhanced energy access, India sees an early peak in energy-related CO_2 emissions and a rapid subsequent decline, putting the country on track for net zero emissions by the mid-2060s.

2.1 Overview of energy demand

India, in common with much of the rest of the world, has been severely affected by the Covid-19 pandemic, in terms of both the immediate toll on human life and the broader impact on livelihoods due to lockdowns and other restrictions. There are multiple possible pathways that India could follow as it emerges from today's crisis (Figure 2.2).

Figure 2.2 ▷ Growth in India GDP and energy demand to 2040 by scenario



Differences between scenarios to 2030 are explained by duration of the pandemic (in DRS) and a faster pace of structural changes in energy production and use (in IVC and SDS).

Note: Pre-crisis shows the *WEO 2019* STEPS projections.

One key near-term uncertainty is the effectiveness of measures to limit the spread of the virus, including how quickly vaccines are made available and distributed. The DRS examines the effects of a prolonged pandemic and a slow economic recovery.

Another key uncertainty is the policy response from the Indian government and others to today's challenges. This includes the extent to which they incorporate energy and sustainability into their recovery strategies, and the extent to which they address structural issues that characterised the economy even before the Covid-19 pandemic. Different assumptions about these policy responses underpin the differences in energy and economic outcomes between the STEPS, the IVC and the SDS.

The electrification of the Indian energy economy continues apace in all scenarios. The share of electricity in total final consumption grows in all sectors, and particularly in the buildings sector, where there is a continued pivot away from traditional biomass and a steady uptake of appliances. In the STEPS, the share of demand met by electricity rises from around 17% today to nearly a quarter by 2040, displacing 60 Mtoe of oil, coal and biomass.

The dominance of coal in India's energy system continues to recede. Coal is the slowest-growing energy source in the STEPS, meaning its share in the energy mix falls from 44% in

2019 to 34% by 2040. As the incumbent fuel in the power sector, coal faces strong competition from renewables in general and from solar PV in particular. However, greater electricity demand and a near-doubling in the use of coal in industry means that the overall demand for coal still rises by over 30% from 2019 to 2040, reaching 770 Mtce.

Oil demand, by contrast, sees a relatively swift comeback from Covid-induced disruption. There is a doubling in oil demand in road transport by 2040 in the STEPS, largely as a result of the addition of 170 million passenger cars and 25 million trucks to the vehicle stock between 2019 and 2040. Oil consumption is also lifted by a tripling of feedstock demand in the petrochemical industry.

Natural gas is the fastest-growing fossil fuel in the STEPS, and the roll-out of gas infrastructure makes the fuel accessible to a growing share of India's industrial base as well as to residential consumers. The share of industrial energy demand accounted for by gas doubles to reach 20% by 2040. Policy support for gas use in transport, both as conventional CNG and bio-CNG, results in a threefold increase in CNG demand.

The energy mix in India becomes much more diverse. Today coal, oil and traditional biomass meet more than 80% of demand. In 2040 modern bioenergy and renewables including solar, wind and hydropower meet nearly a quarter of India's total energy demand in the STEPS. Primary energy use per unit of GDP falls by half as the link between economic growth and energy consumption weakens further.

In the STEPS, total CO_2 emissions in 2040 are 45% higher than in 2019, and emissions per capita also rise, but emissions intensity goes down significantly. India's NDC under the Paris Agreement include a reduction by 2030 in the emissions intensity of GDP by 33-35% compared with 2005 levels. The energy sector achieves this target under the STEPS, with a CO_2 emissions intensity reduction of over 40% by 2030.

In the IVC, key Indian policy objectives are met in full, and this delivers higher economic output together with lower energy demand and lower emissions than in the STEPS. India moves more quickly towards a gas- and renewables-based economy, and the use of traditional biomass in particular fades rapidly as modern cooking fuels gain ground.

The SDS sees a far more profound transformation of India's energy sector. Demand in 2040 is nearly 30% below the level in the STEPS, as the move away from traditional biomass is complemented by concerted efforts to improve energy efficiency across a wide range of end uses. There is a decisive shift away from coal, and solar PV eclipses coal's share of electricity generation a full decade ahead of the STEPS. Oil demand reaches a plateau by the end of the 2020s as the share of alternative fuels in road transport – electricity, gas and bioenergy – rises: together these alternative fuels meet 35% of road transport demand by 2040. Fossil fuels account for less than 60% of primary energy demand by 2040, compared with 72% in the STEPS, while the traditional use of biomass falls to zero by 2030, as clean cooking goals are fully achieved. In the SDS, India sees an early peak in energy-related CO_2 emissions and a rapid subsequent decline, putting the country on track for net zero emissions by the mid-2060s.

Table 2.1 ▷ Energy demand by scenario

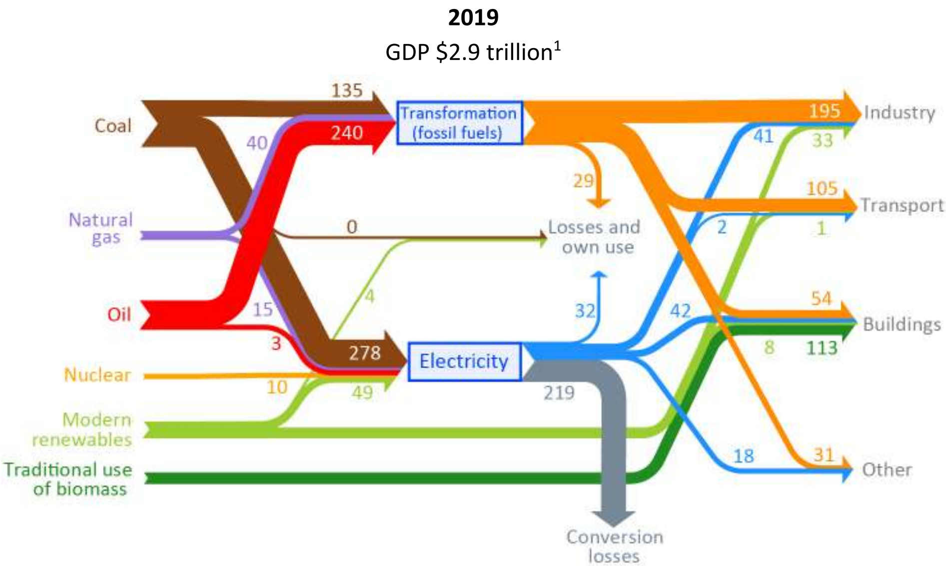
			STEPS		SDS		IVC	
	2000	2019	2030	2040	2030	2040	2030	2040
Primary energy demand (Mtoe)	**441**	**929**	**1 237**	**1 573**	**994**	**1 147**	**1 153**	**1 526**
Total final consumption (Mtoe)	**315**	**621**	**853**	**1 123**	**703**	**843**	**783**	**1 075**
Electricity demand (TWh)	**369**	**1 207**	**1 959**	**3 146**	**1 922**	**2 980**	**2 087**	**3 433**
CO_2 emissions (Gt)	**0.9**	**2.5**	**3.2**	**3.8**	**2.4**	**1.8**	**3.0**	**3.4**
Coal demand (Mtce)	**208**	**590**	**712**	**772**	**454**	**298**	**660**	**712**
Power generation	147	397	453	444	232	60	371	362
Industry	37	141	198	255	169	185	193	240
Natural gas demand (bcm)	**28**	**63**	**131**	**201**	**144**	**210**	**159**	**260**
Power generation	11	17	25	33	49	61	62	95
Industry	4.3	24	61	106	50	84	60	107
Buildings	0.3	3.9	7.3	11	5.2	7.0	9.0	15
Transport	0.1	4.1	9.2	12.1	9.6	11.9	10.9	15.6
Low-carbon gases (bcm)	**0.0**	**0.0**	**6.4**	**21**	**20**	**47**	**10**	**31**
Oil demand (mb/d)	**2.3**	**5.0**	**7.1**	**8.7**	**6.2**	**5.8**	**7.0**	**8.3**
Road transport	0.6	1.9	2.9	3.8	2.4	2.1	3.0	3.8
Aviation and shipping	0.1	0.2	0.4	0.6	0.3	0.4	0.4	0.6
Industry and petrochemicals	0.6	0.9	1.5	1.8	1.2	1.3	1.4	1.7
Buildings	0.4	1.0	1.3	1.4	1.4	1.1	1.4	1.5
Biofuels (Mboe/d)	**0.0**	**0.0**	**0.1**	**0.2**	**0.2**	**0.2**	**0.1**	**0.2**

Notes: Gt = gigatonnes; Mboe/d = million barrels of oil equivalent per day.

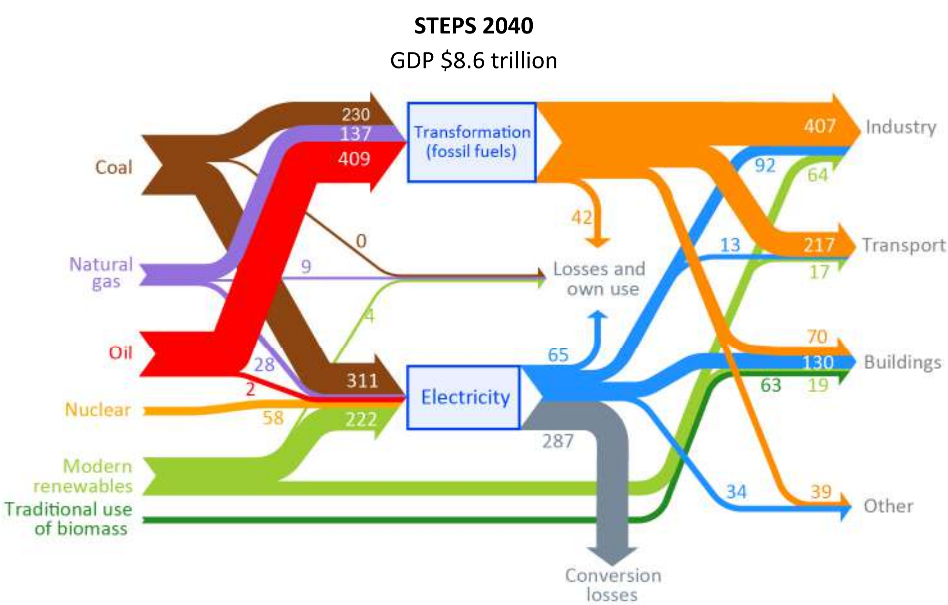
The diagrams in Figure 2.3 provide a visual representation of the flows of energy in India's energy system, and show how they change from 2019 to 2040 in the different scenarios. The diagrams include the various transformation processes used for electricity and for fuels (e.g. refining), and also illustrate the substantial conversion losses that occur in the process of electricity generation. These losses are dramatically reduced in the SDS because of the shift towards non-combustion renewable sources of power.

The flows do not, however, capture the efficiency with which different energy carriers provide useful energy services to consumers. The IVC, for example, leads to a marginally smaller overall energy system than the STEPS in 2040, but supports a larger economy. The SDS is even more efficient, as well as being much less carbon-intensive. This partly stems from its high degree of reliance on electricity. Given that electricity delivers useful energy services with better efficiency than other fuels, the role of electricity is greater in practice than its share in final consumption would suggest.

Figure 2.3 ▷ Evolution of India's energy system by scenario (Mtoe)



Coal, oil and biomass meet over 80% of India's energy demand today.

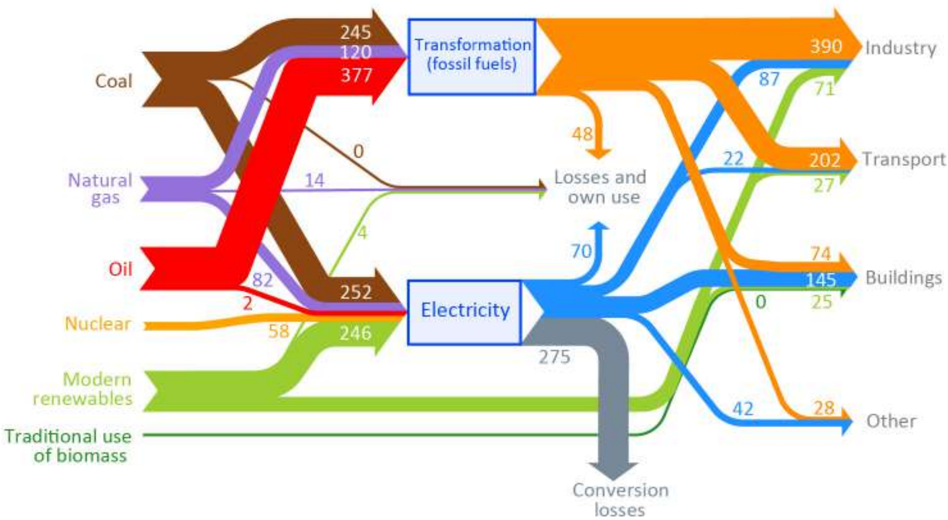


By 2040, India's energy consumption nearly doubles in the STEPS.

[1] All GDP values in this figure are $2019 at market exchange rates.

IVC 2040

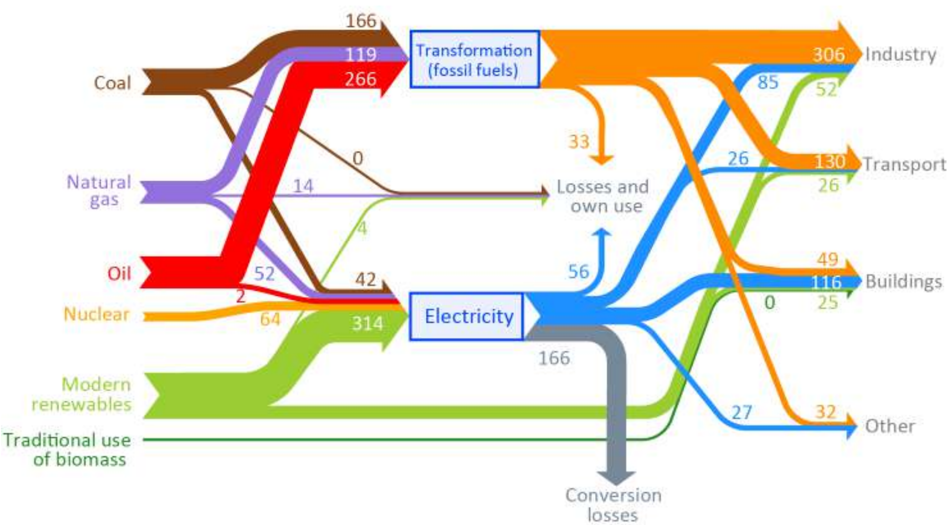
GDP $9.8 trillion



Despite producing a smaller energy system than the STEPS in 2040 the IVC supports a larger economy.

SDS 2040

GDP $8.6 trillion



In 2040, the SDS is more efficient and less carbon-intensive than the STEPS and the IVC.