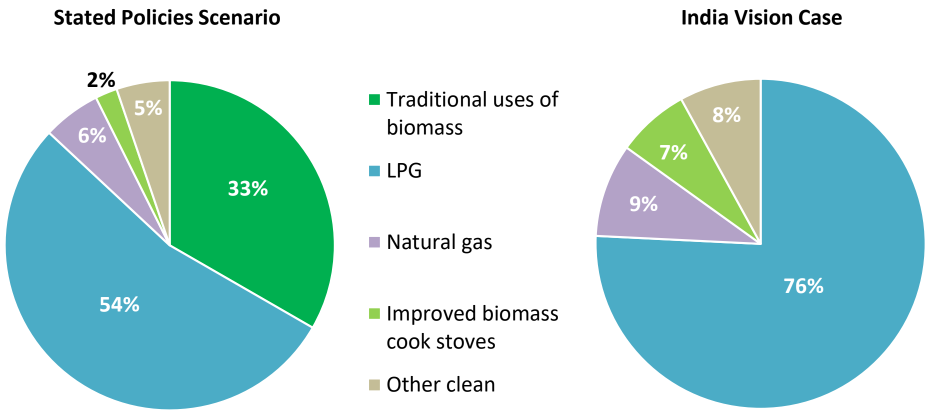
Figure 4.3 ▹ Share of population relying on different fuels for cooking in the STEPS and the IVC, 2030



In the STEPS, traditional uses of biomass continue to be used by 500 million people as the main way of cooking in 2030; in the IVC, this is replaced by a wide range of alternatives.

Note: Fuel shares in the SDS are similar to the IVC.

In the STEPS, more than 170 million people move from the traditional uses of biomass to alternative clean cooking options over the period to 2030. However, taking into account population growth, this leaves around 500 million people without access. As a result, there are still nearly 0.6 million premature deaths due to indoor air pollution in 2030.

In the IVC and the SDS, full access to and full reliance on clean cooking is achieved by 2030, meaning that close to 670 million people gain access to clean cooking over the next 10 years. LPG is the mainstay of clean cooking access efforts; three-quarters of India's population rely primarily on LPG for cooking by 2030, and LPG demand increases by 50% between 2019 and 2030. Investments and incentives are deployed to expand infrastructure for LPG bottling and distribution and for the repair and replacement of broken stoves. Innovative subsidy schemes play a key role in supporting the sustained use of LPG and eliminate stacking of traditional fuels.[3]

The use of improved biomass cook stoves and biogas also makes an important contribution, providing clean cooking to around 180 million people in 2030. They are especially important in locations where there is more resistance to replacing traditional solutions, or where reliable LPG delivery is more difficult to ensure, and in locations with a ready supply of biogas feedstock. In urban areas, natural gas meets an increasing share of cooking needs in the IVC and the SDS through the development of gas distribution infrastructure in major cities. This

[3] Fuel stacking is when a household uses a number of different fuels for different uses, using a mixture of modern and traditional fuels. For example, a household may have access to LPG, but only use it to boil water, and continue with the traditional use of biomass for other cooking needs.

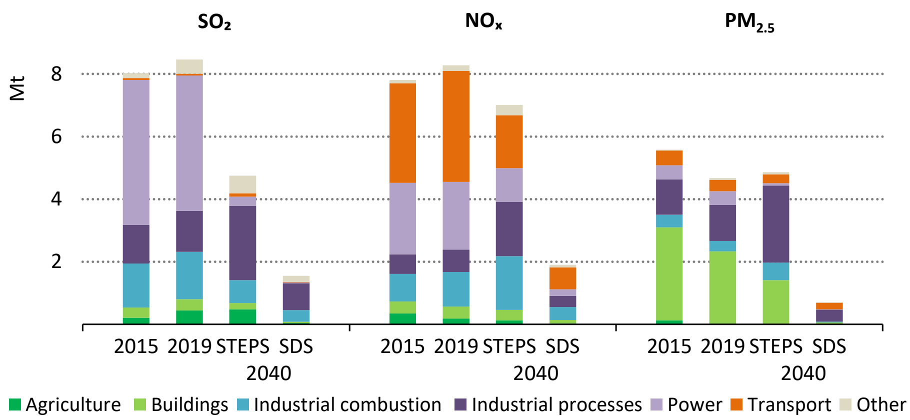
helps to displace LPG in urban areas and allow its increased use in rural areas where the development of gas distribution infrastructure is more challenging. There is also a role for electricity in providing clean cooking access, especially in urban areas, where 6 million people gain access through electric cook stoves by 2030.

4.2.2 Energy and air pollution

Improvements in air quality are crucial for the achievement of multiple SDGs. Ensuring access to clean energy (SDG 7.1) would reduce household air pollution; increasing the share of renewable energy (SDG 7.2) would permanently reduce power sector air pollution; improving energy efficiency (SDG 7.3) would likewise tackle air pollutant concentrations across the energy economy; enhancing access to sustainable transport (SDG 11.2) would improve the overall air quality in cities (SDG 11.6). Air pollution policies also offer direct co-benefits for GHG emissions reductions (SDG 13).

As described in Chapter 1, air pollution has emerged as one of India's most pressing environmental challenges, and the energy sector is the largest source of three of the major air pollutants: nitrogen oxides (NO_X), sulphur dioxide (SO_2) and $PM_{2.5}$. $PM_{2.5}$ is the air pollutant of most concern as concentrations exceed the NAAQS in many monitored locations. NO_X emissions are increasingly problematic in urban areas, while SO_2 concentrations are a particular issue in areas with many thermal power or industrial plants.

Figure 4.4 ▷ Sectoral contributions to air pollution levels in the STEPS and SDS



Air pollutant emissions fall in the power and transport sectors through to 2040 in the STEPS, but only SO_2 emissions fall significantly in overall terms, and industrial emissions grow.

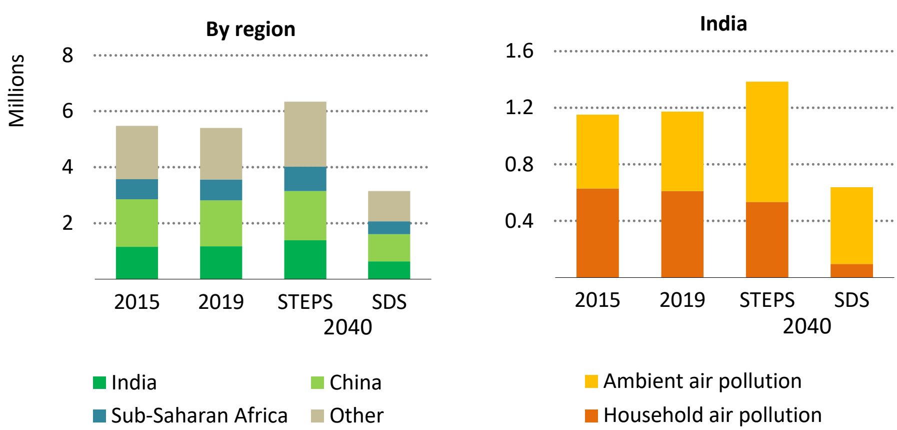
Combustion-related emissions of $PM_{2.5}$ made up more than two-thirds of total household air pollution in 2019. Pollution largely results from the incomplete burning of traditional biomass, such as fuelwood or agricultural residues, used for cooking and heating activities. Policy efforts to promote access to clean cooking led to a 16% decline in emissions between 2015 and 2019 to 4.7 Mt.

The power sector was responsible for half of the 8.5 Mt of total SO_2 emissions in 2019, with industrial activities contributing an additional one-third. Even though India's coal contains relatively little sulphur, coal combustion was the main source of SO_2 emissions. Air pollution control technologies for thermal power plants, such as flue gas desulphurisation, are rarely deployed. The government has recently taken initial steps to rectify this by passing the Environmental Protection Amendment Rules (EPAR) Act.

NO_X emissions have grown slowly in recent years to just over 8 Mt in 2019. About 40% of these emissions stem from road transport, with nearly a further 30% from the power sector. Road transport activity increases with population density, and vehicle tailpipe emissions occur close to the ground, making urban NO_X pollution particularly damaging to health.

In the STEPS, existing policies to curb air pollution are implemented over time, and these limit the level of air pollution despite the rapid rate of population and economic growth over the period to 2040 (Figure 4.4). Increases in urban populations, however, mean that more people are exposed to higher concentration levels of air pollution and so annual premature deaths increase by 0.2 million to nearly 1.4 million in 2040, of which 60% are related to ambient air pollution (Figure 4.5). In the SDS, there is a much more substantial reduction in all air pollutants, meaning that the number of premature deaths in 2040 is more than 50% lower than in the STEPS.

Figure 4.5 ▷ Premature deaths related to air pollution globally and in India



There were nearly 1.2 million premature deaths from air pollution in India in 2019. This number rises by 0.2 million to 2040 in the STEPS but falls by around 0.5 million in the SDS.

There are divergent trends between sectors in air pollution emissions in the STEPS, depending on the stringency of existing and planned regulations.

SO_2 emissions fall by 44% between 2019 and 2040 in the STEPS. A 90% reduction in emissions from the power sector reflects full implementation of the EPAR, which means that the majority of coal-fired capacity is fitted with advanced desulphurisation control technology by 2030. However, neither current nor planned policies adequately monitor and regulate air pollutant emissions from the industry sector, particularly from small and medium enterprises. As a result, emissions of SO_2 from industrial processes, which are only partially covered by existing or planned policies, increase by more than 80% over the 2019-40 period, offsetting a quarter of the reductions in the power sector. NO_X emissions in the STEPS fall by 15% between 2019 and 2040. Conventional vehicles sold after April 2020 are required to meet Bharat Stage VI emission standards, and the number of EVs increases, leading to a fall in road transport NO_X emissions of 60% to 2040. However, NO_X emissions from the industry sector grow by 90% over the same period.

$PM_{2.5}$ emissions in the STEPS increase by 4% through to 2040. Progress in access to clean cooking and heating technologies leads to a 40% reduction in $PM_{2.5}$ emissions from the residential sector, but $PM_{2.5}$ emissions from industrial facilities double over the period to 2040, more than offsetting the reductions elsewhere. While some industrial facilities do use $PM_{2.5}$ air pollution control technologies, there is a lack of effective regulation, and many others do not.

In the SDS, air pollution policies are expanded to all sectors, including the combustion of fossil fuels in industry and industrial processes via advanced control technologies. There is also a rapid expansion of low-carbon energy technologies and a sharp reduction in coal-fired power generation. As a result, power sector air pollutant emissions are almost entirely eliminated, and there is a much larger overall reduction in SO_2 and NO_X than in the STEPS. Universal access to clean cooking and heating technologies in the SDS lowers residential $PM_{2.5}$ pollution to a negligible level from 2030.

4.2.3 CO_2 emissions

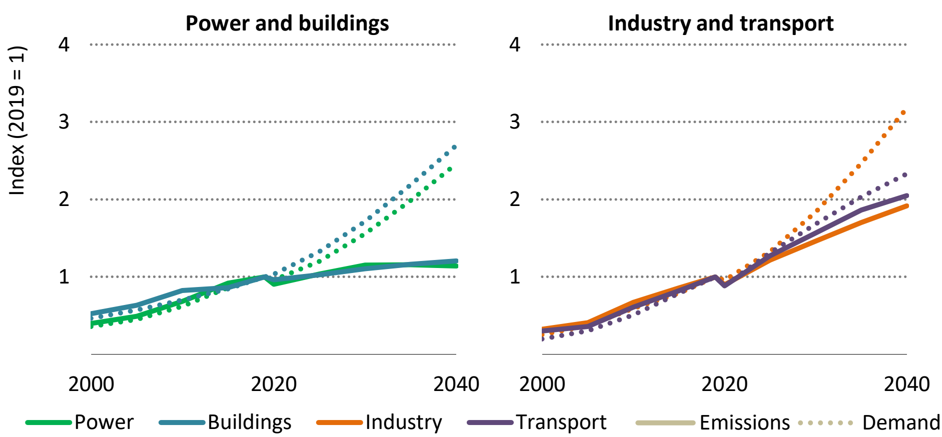
India's large and growing population, its low (but increasing) levels of energy consumption per capita and its high level of projected economic growth could all result in significant levels of future emissions, despite its relatively low per capita emissions today (see Chapter 1). In the STEPS, CO_2 emissions in India rebound quickly from the drop in 2020, and they exceed 2019 levels by 2022. There is a steady slowdown in the pace of growth over the period to 2040: emissions grow by 70 Mt per year between 2019 and 2030, by 60 Mt per year in the first half of the 2030s, and by 45 Mt per year in the second half. Total emissions in 2040 are around 50% greater than 2019 levels, although per capita CO_2 emissions in 2040 (2.4 t CO_2 per capita) are still 40% lower than the global average at that time (4 t CO_2 per capita).

As part of the Paris Agreement, India included in its NDC a target to improve the emissions intensity of its GDP 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. Both of these high-level targets are met in the STEPS: the emissions intensity of GDP in 2030 is 40% lower than in 2005, and nearly 60% of India's electricity capacity in 2030 is non-fossil fuel.

The power sector sees an especially large divergence from past CO_2 emissions trends in the STEPS (Figure 4.6). Between 2019 and 2040, electricity demand increases by nearly 150%

while emissions increase by 15%. The share of coal generation drops from just over 70% in 2019 to less than 35% in 2040, while the share of renewables rises from 20% in 2019 to more than 55% in 2040. Power sector emissions grow slightly over the period to 2030 but then remain on a plateau thereafter.

Figure 4.6 ▷ Changes in demand and CO_2 emissions by sector in the STEPS



In the STEPS, activity and emissions diverge significantly in the power sector and the buildings sector to 2040; breaking these links is harder in industry and transport.

Note: Activity variables: Power = electricity demand; buildings = residential floor space; industry = gross value added; transport = vehicle kilometres.

The buildings sector also sees a loosening of the links between emissions and activity in the STEPS. Residential floor space almost triples between 2019 and 2040. There is also a big increase in electricity use in buildings, which expands by a factor of three between 2019 and 2040. Electricity's share of total fuel use in buildings reaches nearly 50%, up from less than 20% today, reflecting an increasing level of appliance ownership. Ownership of air conditioners grows particularly rapidly. Despite this, emissions from residential buildings increase by less than 50%, and a similar pattern is observed in commercial and public buildings. New buildings are built to increasingly efficient designs, and major efforts are made to develop passive cooling systems. Policies that mandate minimum efficiency performance standards for air conditioners also help to curb some the increase in electricity demand that this would otherwise imply, while part of the growth in electricity demand comes at the expense of less efficient traditional biomass.

There is less of a decoupling between activity and emissions in the industry sector. Cement production grows by 150% between 2019 and 2040, and emissions rise by 100%. A similar trend occurs in steelmaking. An increase in the use of natural gas helps keep emissions lower than they would otherwise be by displacing coal: the share of industry energy demand taken by natural gas more than doubles to 20% in 2040. Nevertheless, total CO_2 emissions from industry grow by more than 90% over the 2019-40 period.

The growth in emissions from transport in the STEPS also remains closely linked to increases in activity. Total emissions from heavy-duty trucks nearly triple over this period as a result of increases in freight activity, although they are somewhat lower than they would otherwise be thanks to the average fuel consumption of heavy-duty trucks on the road in 2040 being almost 20% lower than in 2019. There is also a substantial increase in emissions from passenger cars as ownership increases by a factor of five between 2019 and 2040. This is partly offset by a 30% improvement in the average fuel efficiency of passenger cars using internal combustion engines over the period to 2040, and by increasing sales of electric cars. In 2040, around 10% of the passenger cars and more than 50% of two- and three-wheelers on the road are electric. Nonetheless, the growth in emissions from passenger cars accounts for around 40% of the total increase in transport sector emissions.

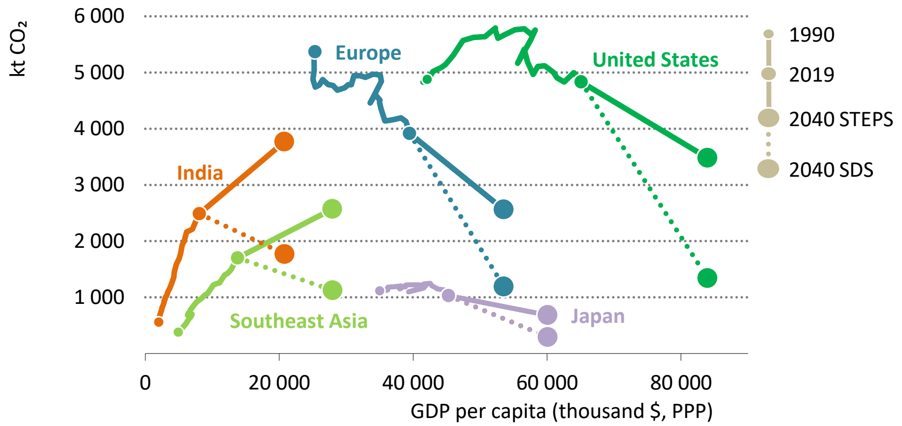
Box 4.1 ▷ How do changes in emissions in India compare with other countries?

Comparisons between the changes in CO_2 emissions in India and in other countries need to be treated with caution. India is at a very different stage of development from many other economies, and it is set to experience rapid population and economic growth for many years to come. India's emissions per capita rank among the lowest in the world today, and it accounts for only about 3% of historic energy sector and industrial process CO_2 emissions since 1850 (compared with around 30% for Europe, 25% the United States and around 15% for China).

In the STEPS, CO_2 emissions in India follow a different trajectory from that in most advanced economies, rising by 50% compared to 2019, to around 3.7 Gt CO_2 over the period to 2040 (Figure 4.7). By 2040, India is the world's second-largest emitting country behind China, although China's emissions (more than 10 Gt CO_2 in 2040) are markedly higher. Nonetheless, India's per capita emissions in 2040 (2.4 t CO_2 per capita) remain far smaller than in most other countries, including the United States (9.5 t CO_2 per capita), China (7.3 t CO_2 per capita), and European countries (3.7 t CO_2 per capita). In the IVC, emissions in India are slightly lower than in the STEPS, despite a higher level of economic growth. In the SDS, emissions in India fall by around 30% over the 2019-40 period.

An increasing number of countries and jurisdictions have announced targets or goals to achieve net-zero CO_2 or GHG emissions. For example, the European Parliament and the European Council have endorsed a target to achieve net-zero GHG emissions in the European Union by 2050, and the Chinese government has announced a target to achieve net-zero CO_2 emissions by 2060. These targets are achieved in full in the SDS. These targets help to spur innovation and provide incentives for consumers and private actors to reduce emissions. They also provide a number of incentives to emissions reductions in India through lower costs for clean energy technologies and a much larger market for low-emissions products and services. In the SDS, India is on track to achieve net-zero emissions around the mid-2060s.

Figure 4.7 ▷ Energy-related CO_2 emissions and GDP per capita by region in the STEPS



As with other emerging and developing market economies, there are major differences between the emissions trajectories for India in the STEPS and in the SDS.

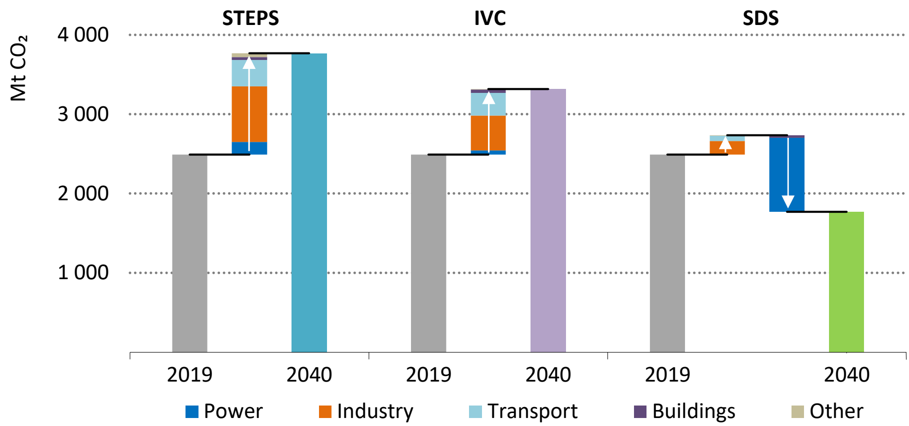
Note: kt = kilotonnes.

Emissions in the IVC rise to a lesser extent than in the STEPS (Figure 4.8). In 2040, CO_2 emissions are around 450 Mt lower in the IVC than in the STEPS, despite stronger economic growth in the IVC and the achievement of universal access to energy. The biggest difference is seen in the industry sector, where CO_2 emissions are around 260 Mt lower in 2040 in the IVC than in the STEPS. This stems mainly from a greater push for the use of more efficient technologies, which slows the increase in coal use, especially in the iron and steel sector. Emissions from the power sector in the IVC in 2040 are also around 100 Mt lower than in the STEPS; much of this is due to the greater growth in the IVC of the use of natural gas in place of coal-fired power, which peaks in the mid-2020s.

The SDS charts a very different course for emissions than the STEPS (Figure 4.8). CO_2 emissions rebound slightly in 2021, but they never return to 2019 levels at any point in the outlook period. By 2030, emissions are around 5% lower than 2019 levels, and in 2040 they are nearly 30% lower. As a result, emissions in India in 2040 are around 1.1 t CO_2 per capita, similar to levels in the mid-2000s. At a sectoral level, the largest differences between the STEPS and the SDS are in the power sector and industry, but there are also much stronger efforts to improve the efficiency of buildings and appliances in the SDS. Nearly 500 million people gain access to clean cooking solutions by 2040 in the SDS through the use of LPG, which leads to a small increase in CO_2 emissions, though this would be more than offset by reductions in other GHGs (methane and nitrous oxide).

In the power sector, emissions from coal-fired power plants fall by 90% between 2019 and 2040 in the SDS. Renewables provide nearly 80% of electricity generation in 2040: generation from solar PV increases by more than 60 TWh every year on average to 2040, while wind generation grows by more than 35 TWh each year. In the SDS, around 40 GW of new solar PV is installed in India on average each year by 2040. To put it in another way, more capacity is added in a single year than was installed up to 2019. Around 15 GW of coal- and gas-fired power plants are also equipped with CCUS in 2040.

Figure 4.8 ▷ Changes in CO_2 emissions in India by scenario, 2019-2040

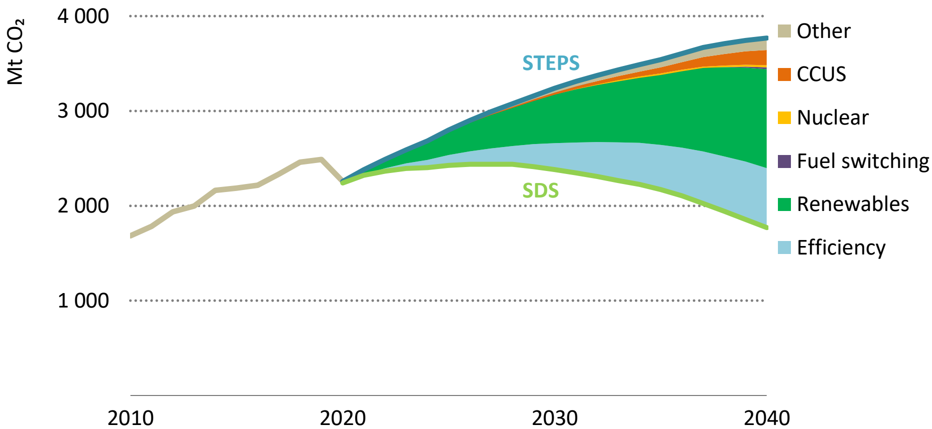


In the STEPS, the industry and transport sectors lead emissions increases; in the SDS, these increases are more muted and there is a marked decline in power sector emissions.

In the industry sector, coal use grows slightly to 2040 in the SDS, but at a much slower pace than in the STEPS. A number of industrial processes are fitted with CCUS to reduce emissions in the SDS, but enhanced efficiency measures play the most important part in curtailing the growth in industrial emissions. In the SDS, fuel use in industry is nearly 25% lower than in the STEPS, despite an identical level of economic output from the industry sector. Electricity also accounts for around one-quarter of total energy use in the industry in 2040, compared with 20% in the STEPS.

In transport, there is much more rapid growth in EVs in the SDS than in the STEPS: by 2040, 60% of passenger cars and 40% of trucks on the road are electric. The use of sustainable biofuels and low-carbon gas and hydrogen-based fuels helps further to reduce the use of petroleum products in trucks, as well as in aviation and maritime shipping. Internal combustion engines are also around 40% more efficient in 2040 than today, reducing emissions from cars and trucks that continue to use them. Transport emissions nonetheless edge up marginally over the period to 2040.

Figure 4.9 ▷ **Energy sector CO_2 emissions and reduction levers in the SDS**



The enhanced deployment of renewables and efficiency causes CO_2 emissions to peak in India in the SDS by 2030 and to decline steadily thereafter.

4.2.4 Managing potential trade-offs and synergies between the SDGs

Charting a course towards achieving all of the SDGs in India in parallel is an immensely challenging undertaking. The relevant policies align in many respects, and there are a number of areas where synergies mean that progress towards one SDG can boost or support other goals. However, there remains a risk that progress in one area could hamper efforts elsewhere; energy transitions could for example have wider social impacts (Box 4.2). The course described in the SDS seeks to avoid or minimise trade-offs to the extent possible.

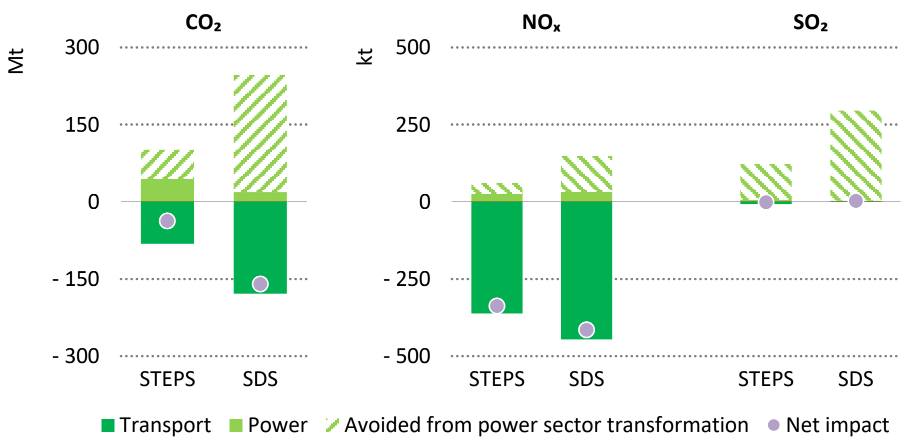
Minimising potential trade-offs between the SDGs

One example of potential trade-offs between policy goals comes in the transport sector. Electrification of road transport substantially reduces air pollution from this sector: a conventional car can emit more than 10 times the NO_X produced by an electric car. However, if coal power plants without any pollution controls are used to generate the electricity for these vehicles, this would increase emissions of SO_2. In this case, generating electricity for an electric car using coal would add about 18 times more SO_2 emissions than using a conventional car (Figure 4.10). Implementation of the EPAR measures to reduce SO_2 emissions from power plants would help ensure that transport electrification leads to a reduction in all air pollutants. Conventional cars also produce CO_2, and the emissions intensity of electricity needs to be less than 700 g CO_2/kWh to 750 g CO_2/kWh for new electric cars to result in fewer emissions than existing conventional passenger cars in India. The average emissions intensity of electricity in India is around this level today. In the STEPS, it falls to around 340 g CO_2/kWh in 2040: if all EVs in 2040 were to be powered using electricity with this emissions intensity, this would lead to power sector emissions of around 45 Mt CO_2.

The oil displaced by EVs in the STEPS would avoid around 80 Mt CO_2, meaning that there would be an overall reduction of around 35 Mt CO_2 from the deployment of EVs. The exact level of savings would, however, depend on the precise time of vehicle charging as the emissions intensity of electricity in 2040 in the STEPS varies considerably throughout the day. It would be lowest during the daytime, when there is a large level of generation from solar PV, and highest at night-time, when coal power dominates the generation mix (see Chapter 3). Recharging electric cars during the daytime would therefore reduce the level of emissions coming from the power sector, and so further increase the overall level of savings.

In the SDS, the average emissions intensity of electricity drops to around 60 g CO_2/kWh in 2040. Electric cars would therefore be significantly less emissions-intensive than conventional cars: powering all EVs in 2040 in the SDS with 60 g CO_2/kWh electricity would lead to a net reduction of more than 150 Mt CO_2. Again, savings could be even larger if vehicles were to be charged during the daytime.

Figure 4.10 ▹ Emissions of CO_2, NO_X and SO_2 from EVs in 2040



Road transport electrification reduces CO_2 and NO_X emissions, but parallel changes in power generation are essential to eliminate potential rises in SO_2 emissions.

Notes: For CO_2, analysis assumes EVs are powered with the average annual emissions intensity of electricity generation. For SO_2, there are measures implemented in the SDS that reduce the sulphur content of gasoline and diesel to very low levels, so EVs displace slightly smaller quantities of SO_2 than in the STEPS.

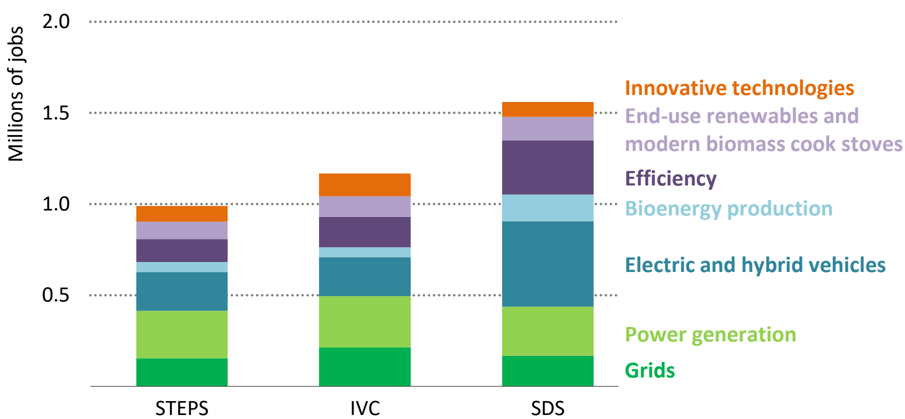
Turning to another part of the energy sector, India has a target to convert around 100 Mt of coal to natural gas using coal gasification by 2030, which points to another potential trade-off between air pollution and CO_2 emissions. The use of natural gas in cities would reduce emissions of SO_X and $PM_{2.5}$, but coal gasification is a very CO_2-emissions intensive way of producing natural gas. Achieving the government's target would lead to an additional 150 Mt CO_2 emissions by 2030, compared with a case where the natural gas was produced from conventional reservoirs. CCUS offers a possible way of avoiding these additional emissions.

Finally, the energy transition envisaged in the SDS requires an increase in investment expenditure compared with the STEPS: a cumulative increase of $1.4 trillion of investments in a wide range of clean energy technologies would be needed over the period 2019-40. To the extent that this relies on direct government expenditure, it would require increases in taxes, possibly including energy taxes, which could in turn increase end-user prices and risk damaging progress on energy access. This could be avoided by mobilising spending from private sources to ensure adequate investment for secure and sustainable energy transitions. As discussed in the next section, such mobilisation depends on improving effective regulatory procedures, reforming energy taxes and reducing risks for private investment.

Box 4.2 ▷ The employment impacts of energy transitions

A transformation of India's energy sector will inevitably have implications for employment as opportunities in cleaner energy and related sectors increase and jobs in traditional parts of the energy economy become scarcer. The changes involved will have a major impact on the lives of many people and communities, and they call for a strategic approach to secure a just transition with a strong focus on training and retraining.

Figure 4.11 ▷ New full-time jobs added in India by 2030 by scenario and investment segment



Clean energy employment grows in all scenarios, especially in the SDS; the scale of the growth underlines the need for training and retraining.

Across all scenarios, employment ramps up rapidly in grids and clean power generation, EV manufacturing, end-use efficiency and renewables, including in appliance manufacturing and the deployment of modern cook stoves (Figure 4.11). In the SDS, employment in these sectors grows notably higher than in the other scenarios, reaching 1.6 million full-time equivalent jobs, largely due to substantial increases in employment in EV manufacturing and in efficiency. In the SDS, strategic decisions taken early to limit growth in conventional manufacturing segments minimise the need for retraining and later retooling of manufacturing lines. The IVC relies heavily on renewable generation and batteries, and employment levels in those areas are comparable to those in SDS.

The location of these jobs is an important factor for managing transitions, especially when directing programmes and funding. Jobs in construction and delivery of retrofits have a relatively even geographic distribution: retrofits can be performed wherever there are buildings. Manufacturing and mining jobs, however, are geographically specific, and are often vitally important to the local area. For example, coal is mostly produced in the poorer states of India today, and coal extraction is the main economic activity in several regions. In the SDS, there is an 85% reduction in coal-fired power generation and a 60% reduction in domestic coal mining between 2019 and 2040. This would inevitably entail large job losses among the roughly 500 000 official workers who depend on the industry, and more among informal workers. Unless carefully managed, this could have major social and economic implications in local economies and communities.

There is much that could be done to support those who would be affected. For example, regions where jobs are lost due to the energy transition could be focal regions for investments in emerging sectors, such as battery production, and funding could be provided for environmental restoration in mining regions, which could provide near-term employment for those approaching retirement as others are retrained. A comprehensive communication strategy, together with well-resourced reskilling and regional revitalisation programmes, would be essential to enable workers in incumbent industries to find alternative livelihoods (IEA, 2020b). Retraining programmes should be informed by a process of mapping skills between displaced and growing occupational segments requiring similar skill sets (ILO, 2011).

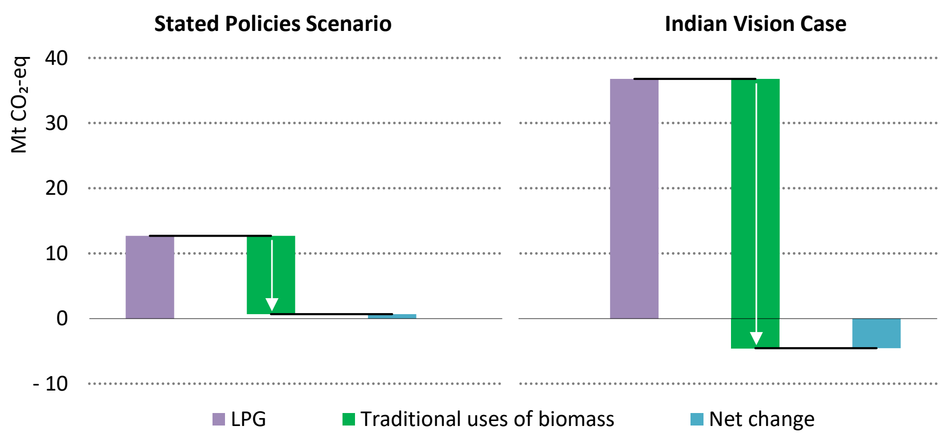
Identifying and maximising synergies

There is a great deal of potential for synergies between improving energy access and reducing air pollution. In 2019, there were around 600 000 premature deaths associated with household air pollution in India, most of which were associated with traditional uses of biomass for cooking. Achieving full access to clean cooking solutions by 2030, as in both the IVC and the SDS, reduces this to fewer than 100 000 deaths in 2030.

Reducing the traditional use of bioenergy for cooking would also reduce GHG emissions. The majority of people gaining access to clean cooking achieve this through the use of LPG. While the achievement of clean cooking for all would lead to an increase in CO_2 emissions, this would be more than offset in terms of overall GHG emissions by a reduction in methane and nitrous oxide emissions arising from the traditional uses of biomass (Figure 4.12). More clean cooking with LPG could also reduce deforestation and other environmental and water stresses that are often associated with the collection of biomass and charcoal.

There is also a great deal of scope for synergies between reducing GHG emissions and achieving other sustainability objectives. For example, greater use of renewables would reduce emissions, and would at the same time reduce water stress (Box 4.3).

Figure 4.12 ▻ Changes in GHG emissions from providing clean cooking by scenario, 2019-2040



Higher CO_2 emissions from increased LPG consumption for access in the IVC are more than offset by a reduction in other GHGs, notably methane, from the traditional use of biomass.

Note: CO_2-eq = carbon dioxide equivalent.

Box 4.3 ▻ Reducing water needs in the power sector

India's power sector withdrew over 20 bcm of water and consumed more than 3 bcm in 2019, almost all of it used for cooling and washing in coal power plants.[4] Yet almost 35% of India's coal power plant capacity that uses freshwater cooling is located in areas that are categorised as extremely water stressed, and a further 16% is in areas experiencing high water stress.[5]

India has put in place a number of measures to reduce levels of water withdrawal. All existing and new thermal power plants are required to switch to tower cooling technologies and to cap their water consumption, and plants located within a 50 km radius of municipal sewage treatment plants are required to use treated sewage water. Nevertheless, just 8% of all coal plants in India have access to treated wastewater and

[4] Water consumption is the volume withdrawn from a source that is not returned (i.e. is evaporated or transported to another location) and is no longer available for other users. Water withdrawals are the volume of water removed from a source and are always greater than or equal to water consumption.

[5] Baseline water stress is taken from the World Resources Institute's Aqueduct database. Stress levels are based on the ratio of water withdrawals to available renewable ground and surface water supplies. For high stress the ratio is 40-80%, and for extremely high it is greater than 80%.

are able to use it completely or partially to meet their cooling water needs; there are also water quality challenges and competition from other uses, such as irrigation.

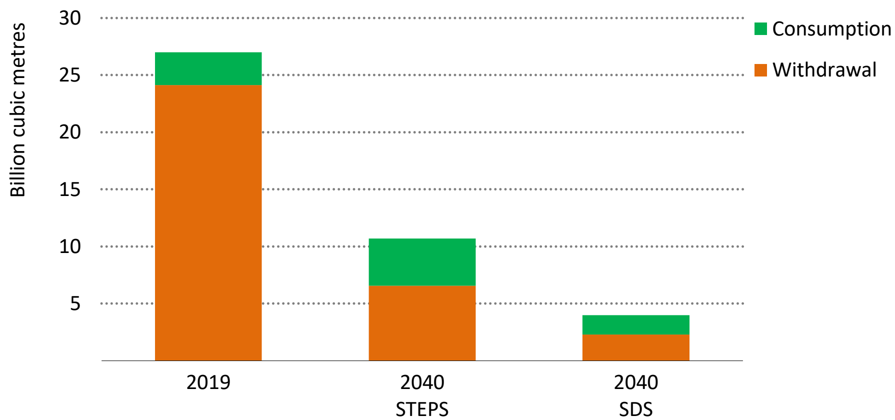
To alleviate water stress further, operators could improve power plant efficiency, deploy dry cooling plants, retrofit existing plants to use dry cooling, and make better use of non-fresh water and water recycling.

A number of low-carbon energy options – most notably nuclear, bioenergy and concentrating solar power – also require access to water and could be limited by water availability in the future. Decisions about plant locations and cooling technology options therefore need to take into account water availability and competing water demands.

The STEPS sees a significant decrease in water withdrawals to 8 bcm in 2040 as a result of increases in the share of electricity coming from use of renewables and regulations on water use in thermal power plants (Figure 4.13). However, water consumption grows by 65% to 2040 as a result of India's policy for all thermal power plants to use tower cooling.

The SDS sees water withdrawals fall to less than 3 bcm in 2040, reflecting a major reduction in coal-fired power generation. The decline in coal-fired generation also means that water consumption falls by around 40% to 2040, although this is offset slightly by increases in consumption from modern forms of biomass, nuclear and concentrating solar power.

Figure 4.13 ▻ Power sector freshwater withdrawals and consumption



Water consumption from coal-fired power generation falls by 90% in the SDS; this is offset to a very limited extent by an uptick from water-intensive low-carbon sources.

4

4.3 Clean energy investment and finance

India currently devotes nearly 3% of its GDP to energy investment, and an increasing share of this investment is going into clean energy.[6] This clearly represents an investment opportunity, but it is one that comes at a time of increased economic uncertainty and new risks. The pandemic has disrupted supply chains, weakened state discoms, and undermined access to finance, adding new challenges to persistent underlying structural issues. Despite this, interest in investing in India's clean energy transition remains high, as evidenced by a record level of awards of solar PV tenders and by the response of policies, such as Delhi's new EV scheme.

India's investment response to the pandemic has so far focused on short-term measures to ease liquidity and support project development. Efforts to navigate a rapidly changing market situation while addressing longer-term issues will determine how the outlook evolves over the next decade. Mobilising investments will depend on improving the availability of finance from a diverse range of actors and instruments, and that in turn will depend in part on appropriate long-term policy design.

4.3.1 Investment needs under different energy pathways

Under any energy pathway, India's energy system would require a significant amount of investment and a shift towards clean energy and grids. At nearly $160 billion, annual spending in STEPS reaches double the level of the past five years by 2030. Half of this growth comes from power, led by grids, renewables and battery storage. Spending continues for fossil fuel-based power, supported by plants under construction, but the level of expenditure steps down to much lower levels by 2030. Investment in fuel supply grows modestly for oil and gas and biofuels in STEPS, and declines for coal by 2030. There is also a significant rise in support for purchases of EVs, whose sales top 8 million in 2030, as well as for investment in efficiency and renewable heating applications.

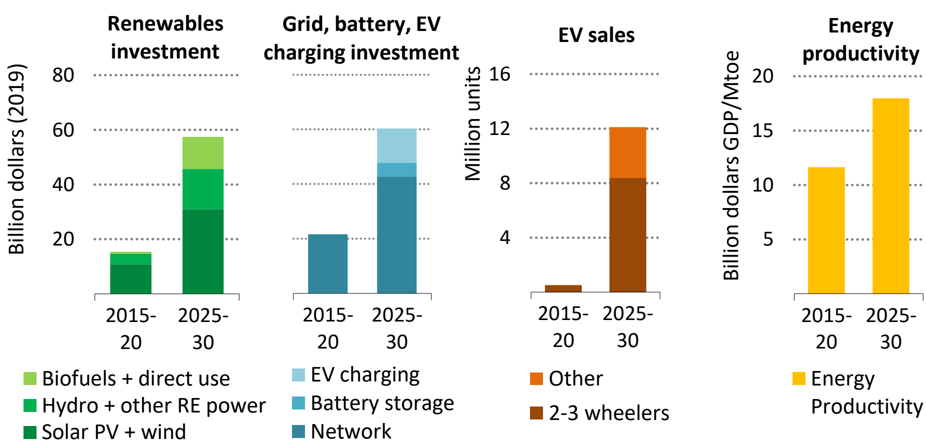
The SDS sees a level of investment by 2030 that is 35% higher than in the STEPS, and three times greater than that during 2015 to 2020 (Figure 4.14). Over 90% of the annual $200 billion in the SDS from 2025-30 goes to clean energy and electricity networks, up from 60% over the past five years. Renewables-based power investment, led by solar PV and wind, triples to almost $50 billion a year, supported by a doubling of spending on electricity grids. System flexibility and emissions reductions are further supported by higher levels of investment in battery storage, as well as by increases in gas-fired power, hydropower and nuclear power.

Investment in the direct use of renewables in buildings, industry and transport, especially bioenergy and biofuels, also rises in the SDS, reaching over $10 billion annually. Spending increases to over $10 billion by 2030 on the electrification of the vehicle fleet too, bringing

[6] Clean energy investment includes low-carbon fuels, renewable power, nuclear power, battery storage, renewables for end use, energy efficiency, EVs and chargers, and CCUS.

about an acceleration of EV sales to 12 million annually on average from 2025 to 2030, 70% of which are two- and three-wheeled vehicles, as well as a rapid roll-out of charging infrastructure. This is all enabled by more stringent consumption measures and investment in energy management systems, more efficient appliances and new industrial motors. Overall energy productivity increases by 55% in the SDS, led by improvements in the energy intensity of commercial buildings and of key industrial sectors such as cement and steel. By 2030, investment in CCUS starts to support emissions reductions in heavy industry and coal power, while investment in new unabated coal power dips to near zero by mid-decade.

Figure 4.14 ▷ Annual average clean energy-related investment and activity indicators by sector in the SDS



To meet sustainability goals, more than 90% of India's energy investment in the SDS goes to clean energy and grids, with sizeable allocations of capital for renewables and efficiency.

Notes: RE = renewable energy. Energy efficiency is shown as gains in energy productivity (economic output per unit of consumption). The 2025-30 time period is used as an indicative post-recovery benchmark.

The role of investment frameworks and the industry and financial landscape

Mobilising capital will depend first on strengthening the enabling frameworks for investment and addressing cross-cutting factors, notably those pertaining to country risks (the macroeconomic situation, particularly currency volatility) and policy and regulatory risks (investors point to issues over "contract certainty" – the combination of contract sanctity and policy certainty – as a key challenge). Other cross-cutting risks include burdensome and slow administrative processes for obtaining project permits, rigid labour regulations, difficulties associated with land acquisition and the relatively low level of availability of long-term, fixed-rate debt (Table 4.2).

The investment outlook also depends on the type of companies developing projects and the way they manage risks and capital budgets. PSUs are the main financiers of electricity grids and are subject to price regulation risk (tariffs revised periodically by the regulator), while investors in utility-scale renewables obtain a price for electricity that is agreed up front and set in a long-term contract. However, India's electricity discoms are subject to cash flow and performance risks that have knock-on effects for the rest of the system, including transmission companies and privately owned generators who remain dependent on reliable dispatching, balancing and payments. Timely investment in any part of the energy system is to a large extent dependent on all parts of the energy system performing at an adequate level.

Table 4.2 ▷ Key factors affecting risks and returns and common types of developers for clean energy-related investments in India

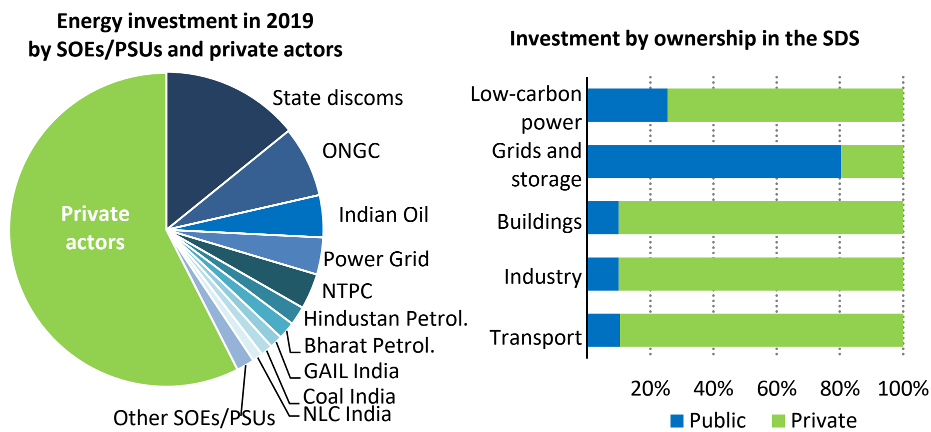
Selected subsector	Key factors affecting risks and returns	Most common developer type
Biofuels and biogases	• Sustainable feedstock supply chains and domestic fuel pricing • Land acquisition	• PSUs and MSMEs
Utility-scale renewable power	• Power purchase and dispatch • Contract certainty • Land acquisition	• Listed and unlisted (i.e. privately held) companies, mainly large, domestic companies
Distributed renewable power	• Retail tariffs and cross-subsidies • Enabling infrastructure • Regulatory risk (access, ownership)	• Corporate consumers, PSUs and households
Electric grids and battery storage	• Regulatory risk (tariff setting) • Volume risk (e.g. line utilisation) • Uncertain business model (storage)	• PSUs, some listed (e.g. Power Grid) and other large companies (inter-state transmission)
Energy efficiency	• Retail tariffs and cross-subsidies • Establishing reliable baseline and measurement/verification of savings • Creditworthiness of small developers	• Large domestic companies, MSMEs, ESCOs, households
Electric mobility	• Enabling infrastructure (e.g. pace of electric charger deployment) • Retail tariffs and cross-subsidies • Performance issues	• State-owned and private transport companies • Corporate consumers and households
Renewable heat applications	• Retail tariffs and cross-subsidies • Creditworthiness of small developers	• Large domestic companies, MSMEs, ESCOs, households

Note: PSUs = public sector undertakings, state-owned enterprises, majority-owned by the central or state governments. MSMEs = micro, small and medium-sized enterprises, ESCOs = energy service companies.

At nearly $85 billion in 2019 (see Chapter 1), energy accounts for around 10% of investment in India. Large, domestically listed energy supply companies play an important role in funding the sector: they account for nearly half of energy investment (Figure 4.15). The other half of energy investment comes from unlisted state-owned companies (e.g. discoms) and private actors, such as MSMEs, individual households and, to a lesser extent, international companies.

PSUs are likely to play a continued important role over the next decade, accounting for around 30% of the ownership of new energy capital over 2025-2030 in the SDS. While 2020 energy investment declined by around 15%, the government is pressing PSUs to meet initial capital budgeting targets in order to sustain employment. Spending is set to decline in the fossil fuel sectors where they are most prominent, but PSUs also account for over 80% of investment in electricity grids over the period. Many PSUs face increased financial strain as a result of the crisis, however, and this is affecting their ability to invest and serve as creditworthy purchasers from private players. Some PSUs are making efforts to diversify: NTPC has signalled a shift towards investing in solar PV to increase its renewable power generation capacity up to 25% by 2032, and Indian Railways – a major consumer – has announced a net-zero emissions target by 2030.

Figure 4.15 ▷ Energy investment by major company in 2019 (left) and ownership of energy capital in the SDS (2025-2030) (right)



Around 70% of clean energy-related investment will be met by private sources; public finance and policy design are critical to mobilise capital to meet diverse financing needs.

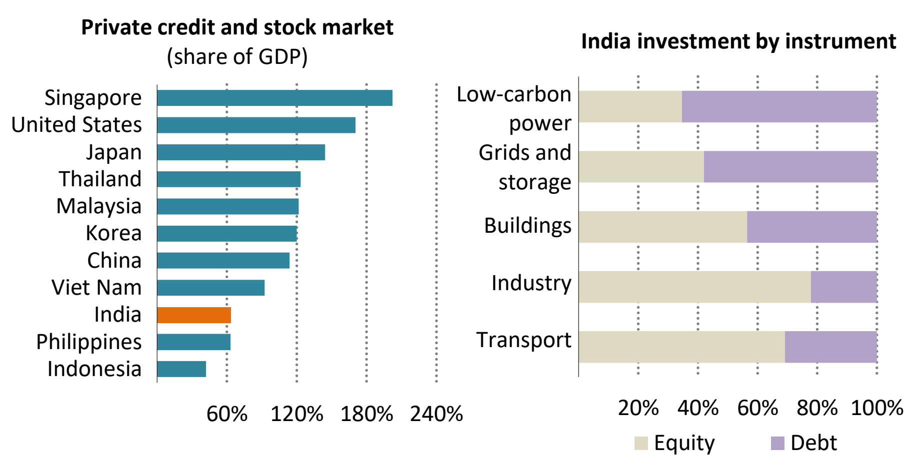
Notes: Petrol. = petroleum; ONGC = Oil and Natural Gas Corporation Limited. The ownership projections are based on estimates of the share of investment that is carried out by state-owned enterprises and government sponsors (public sources) compared with that led by private actors.

Some large private actors have also increased their clean energy ambitions. Reliance Industries has announced a 2035 net-zero target, and other energy supply companies (e.g. Tata Group, Adani Transmission, Suzlon and Essar Oil and Gas) have committed to set emissions reduction goals under the Declaration of the Private Sector on Climate Change, though implementation details are not yet available. Automotive companies in India plan to spend around $500 million in support of EV deployment in the next few years. An increased emphasis on environmental, social and governance (ESG) factors is also starting to influence disclosure and strategies. Among the top listed companies, over half report ESG data, though only around 5% disclose details on how capital expenditure aligns with sustainability goals.

We estimate that 70% of investment over the next decade in sectors critical to meeting the SDS would need to come from privately-owned projects, which are set to play an important part in scaling up renewables, efficiency and new technologies. In recent years, clean energy investments have been carried out more by newer and less well capitalised companies, raising questions over their ability to fund the transition. In some sectors, the industry has become more mature: in utility-scale solar PV and wind, there has been a shift towards fewer large developers with greater risk-taking capacity, which has helped projects to access lower cost funding (IEA/CEEW, 2020). However, clean energy sectors generally still lack scale and diversified access to financing. Some investments in efficiency are carried out by large, established companies, but others are made by MSMEs and smaller ESCOs. Much of the investment in clean energy is also likely to come through unlisted companies that face barriers in raising funding from capital markets. Foreign direct investment and enhancement of domestic sources are both key to meeting financing needs.

Viewed from this perspective, India's financial system development lags behind that in many other emerging market and developing economies, and doubts about the availability of finance puts a question mark against future investment plans (Figure 4.16). In 2020, both debt and equity market risk premiums increased in the first half of the year, reflecting capital outflows amid the pandemic, and offsetting some of the moderating effect from more expansive monetary policy and central bank liquidity support. As a result, the economy-wide cost of capital in India remains high, with risks to the upside in the event of potential further economic fallout.

Figure 4.16 ▷ India's financial system development (left) and clean energy investment in the SDS by financing instrument, 2025-2030 (right)



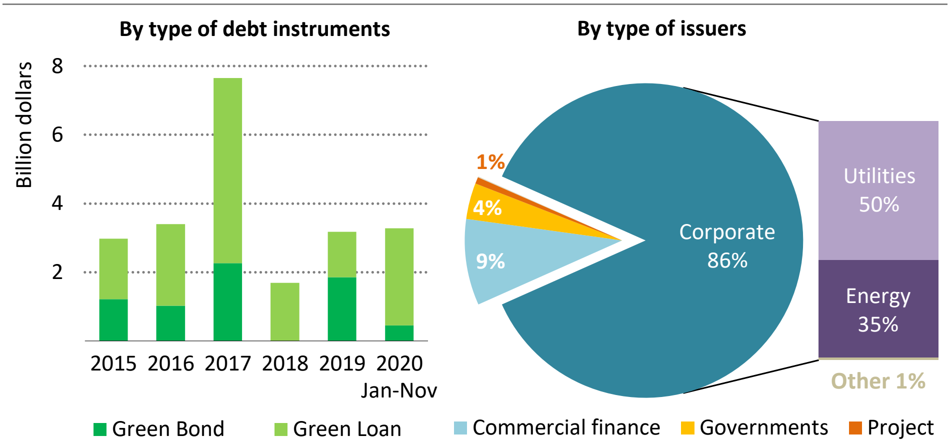
A diverse range of equity and debt instruments is needed to fund clean energy-related investment in the SDS, and access to finance represents a potential barrier to meeting sustainability goals.

Notes: Instruments estimates are based on current observed capital structures by sector, derived from financing data on companies and consumers (for balance sheet financing) and assets (for project finance), applied to SDS investment projections; equity includes grants.

On the equity side, economy-wide required rates of return are generally high, at around 15%, reflecting cross-cutting risks to investing but also the underdevelopment of capital markets. Stock market capitalisation as a share of GDP stands at nearly 65%, compared with the global weighted average of over 100%. India is effective at bringing new companies to market in terms of initial public offerings (IPOs), though relatively few equity market listings have been in the energy sector. Since 2015, industrial sectors have accounted for around 45% of IPOs, and consumer firms such as automotive, retail and textile companies for a further 30%; less than 10% of IPOs were for energy-related companies (mostly renewables companies).

Debt financing largely comes from a mixture of domestic banks and non-banking financial companies, such as the Power Finance Corporation (Figure 4.17). The average of private credit and stock market capitalisation as a share of GDP stands around 60%, compared with a global average of around 100%. While long-tenure debt is generally available for renewable power, regulatory rules on sector lending mean that renewables compete for the same pool of bank capital as thermal power, where an increase in stressed assets has put pressure on bank lending (see below). Debt is more constrained on the consumer side: only around 15% of MSMEs have formal access to credit, and many rely instead on the more expensive and less transparent informal market for lending. While MSMEs are recognised as a priority lending sector, there are no sectoral lending requirements for efficiency.

Figure 4.17 ⊳ Sustainable debt issuance and types of issuers in India



India is one of the largest emerging market issuers of sustainable debt. Although issuance has not grown in recent years, it remained resilient in 2020.

Sources: IEA analysis based on data from Bloomberg (2020) and BNEF (2020).

Meeting India's clean energy investment needs over the next decade will require a financial system that can better match the capital needs of energy companies and assets. The closer that India moves towards an SDS pathway, the more investment needs will increase, and the more important the availability of debt finance will become. A shift from investment in fuels to investment in the electricity sector will increase investment requirements; additional investment will also be needed in end-use sectors. Debt shares within these sectors in India are lower than in advanced economies, however, pointing to a need to develop domestic credit markets to support lower-cost financing.

Attracting greater shares of debt depends on addressing the sector-level issues described below, as well as reforming sectoral lending rules, deepening corporate bond markets and fostering markets for new instruments. Better availability of default protection and risk-transfer mechanisms would help enhance corporate borrowing (CPI, 2020). Sustainable debt issuance has surged globally, and India is one of the largest emerging market issuer of green bonds, except for China. Despite the Covid-19 pandemic, sustainable debt issuance in India remained resilient in 2020, supported mostly by energy companies and utilities. Over 90% of proceeds went to renewable power, with a smaller share to low-carbon transport. If it is to scale up, the market is likely to require more integrated frameworks for measurement, verification and reporting, and more diversity in issuers. The creation of a sustainable finance taxonomy, based on a list of green economic activities, could support this. There is also scope for warehousing projects into securities, such as infrastructure and real estate investment trusts (INVITs and REITs), which spread risks and transaction costs.

4.3.2 Key issues and success factors for financing clean energy transitions

Whichever way India's energy sector evolves from here, the scale of the country's energy investment needs is huge, especially in the power and end-use sectors. In the second part of this section, we zoom in on four issues that are critical to the prospects for a more sustainable and secure energy sector:

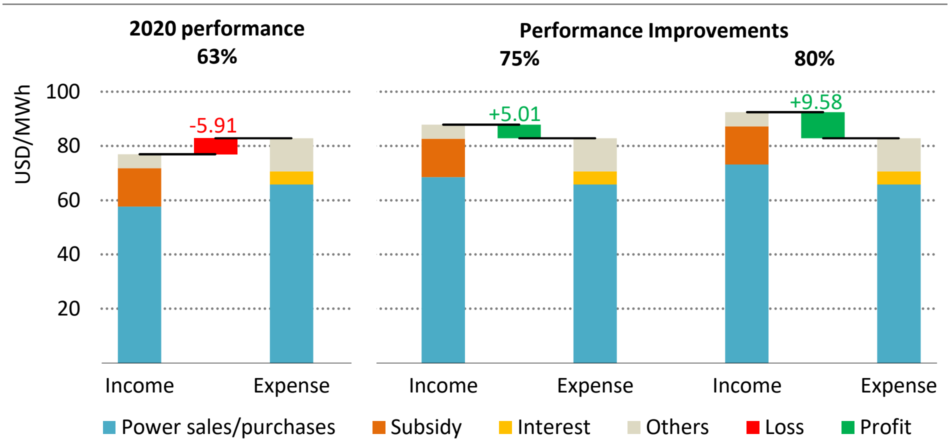
- the financial performance of the state electricity discoms
- the question of how to scale up investment in utility-scale renewable projects
- the different approaches required to finance efficiency improvements, transport electrification and smaller-scale clean energy projects
- the linkages with existing, often poorly performing investments in other parts of India's energy sector.

Improving the financial performance of state distribution companies

State electricity discoms represent the biggest financial uncertainty in the value chain of India's power sector investment. These utilities suffer from persistent revenue shortfalls, in large part due to poor operational performance in billing of power, difficulties in collection of sales from consumers, and high levels of aggregate technical and commercial (AT&C) losses. Performance varies widely by state but overall, outstanding dues to generation companies climbed from nearly $4 billion in September 2017 to over $18 billion in September 2020 (PFC Consulting, 2020). The situation affects the ability of utilities to invest in the expansion and modernisation of grids, honour contracts with renewable and thermal generators, and integrate clean energy technologies, such as distributed resources, that may affect their top-line revenues. As described above, uncertainty over power purchase remains a critical risk for project developers, challenging efforts to manage the cost of energy transitions.

In 2015, the government launched the UDAY initiative in an effort to improve discom finances. This involved state governments writing off up to 75% of their debt and restructuring the remaining loans with a concessional interest rate of only 10 basis points over the central bank's base rate. While UDAY has reduced debt burdens, it has not translated into dramatic improvements in key performance indicators that would denote improved profitability. Recent annual data show the average cost of electricity supply remaining 8% higher than revenues, an imbalance that has only modestly improved over the past three years. The pandemic has not helped: discoms experienced a 15% reduction in demand during March-June compared with the same period in 2019, mostly due to corporate and industrial power users, and this has translated into $3 billion to $4 billion in lost revenues. In March 2020, the central government announced a liquidity scheme of $13 billion to help reduce outstanding dues to generators.

Figure 4.18 ▷ State discom income and impact of enhanced performance in billing, collections and reduction of losses, 2020



Revenue shortfalls for state discoms have led to significant arrears to generators; better performance on key indicators would help enhance profitability.

Notes: Performance is calculated based on billing, collecting and AC&T losses rates. Current value is estimated at 63% (85% billing rate, 93% collection rate and 21% AC&T losses). Improvements in key performance indicators are assumed to benefit each consumer category (domestic, commercial, agricultural, industrial and others) pro rata with its sales.

Sources: IEA analysis based on Power Finance Corporation (2020) and POSOCO (2020).

Narrowing the cost-revenue gap is critical to enhancing financial performance and clearing the backlog of overdue payments. Three-quarters of discom income stems from sales to consumers, 15% from tariff subsidies and 3% from revenue grants under UDAY. Around 80%

of their expenses come from the cost of power purchase and generation, with the remainder from administrative, labour and financing costs. Power costs are determined by the mix of generation, fuel costs and provisions under long-term PPAs, and revenues are influenced by tariff structures and demand.

While larger energy market and policy developments will inevitably have a big impact on the cost-revenue gap, utilities can make important strides towards profitability by focusing efforts on improving billing efficiency, collection efficiency, and reducing AT&C losses. We estimate that discoms were able to monetise only 63% of the electricity they distributed in 2020 due to difficulties in these areas. Raising this to 75% or more would bring them back to profitability (Figure 4.18).

Such improvements may require increased investment and operational measures geared towards metering, billing and collection systems as well as the upgrade and monitoring of distribution grids to reduce losses. However, while distribution companies could improve business profitability by taking such measures, their efforts would be enhanced by better governance and by structural reforms. Such reforms might include government action to improve the cost-reflectiveness of tariffs, increase the share of low-cost renewables, and address the financial implications of existing thermal power assets (see below). They might also extend to opening the distribution segment up to competition, in line with government plans to privatise utilities in union territories.

Mobilising investment for utility-scale renewables projects

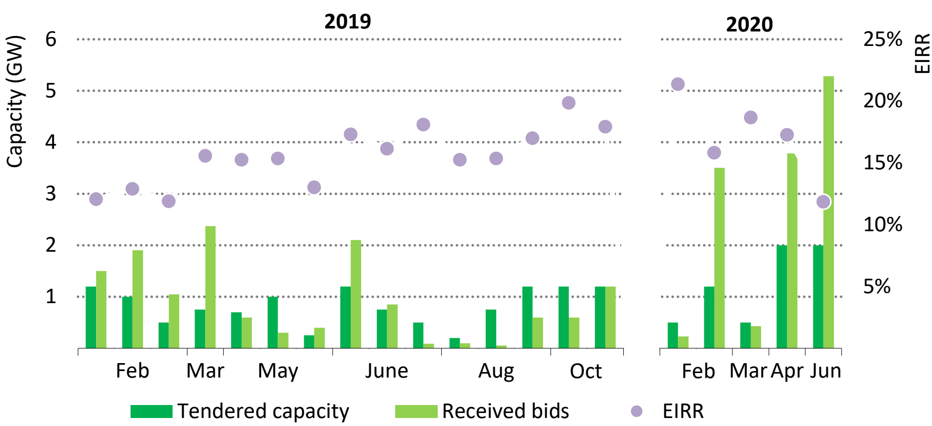
Investment in renewable power grew by almost 55% between 2014 and 2019, and interest in investing remains strong, as evidenced by the high level of solar PV bids (15 GW) in the first half of 2020, even if no wind capacity was awarded in the first half of 2020. While this solar PV tendering was influenced by the exercise of a large (8 GW) option awarded under a previous manufacturing-linked tender, the rest of the capacity awarded during the first half of 2020 topped that from the first half of 2019, and was 75% higher than in the first half of 2018.

The impacts of the economic crisis nonetheless add additional layers of risk to the massive scaling-up of investment that would be needed in the IVC or SDS. Meeting the ambitious 2030 target for renewable electricity would require adding more than 30 GW of renewable capacity each year between 2020 and 2030, and this has a much better chance of happening if action is taken to address persistent risks around power purchase, land acquisition and availability of transmission, as well as policy and regulatory uncertainties, such as those related to potential new trade measures for solar PV.

At the same time, financing terms for projects, and the risk and return proposition facing developers, have begun to shift, as illustrated in analysis from IEA and CEEW on tender results over 2019 to mid-2020 (IEA/CEEW, 2020). On the project debt side, availability and pricing have remained stable, with differences mainly due to off-taker risks. Long tenors (16-18 years) and high debt ratios (around 75%) remain the norm. On the equity side, the estimated equity internal rate of return (EIRR; i.e. the minimum return required by equity holders) for solar PV projects stood at around 15% on a weighted average basis (by awarded capacity) over the course of 2019 and the first half of 2020, with differences depending on off-taker risks and type of site.

For example, while expectations of returns for projects with central off-takers and Gujarat distribution companies were similar, they were 80-200 basis points higher where the state utility off-taker presented higher credit risk. Competition in tenders has also been an important determinant of return expectations. In the first half of 2019, bids far outpaced tendered capacity, helping keep EIRRs down around 14%. However, from the second half of the year through mid-2020, returns rose to 16-17% (Figure 4.19), in the face of new policy and market uncertainty—such as potential renegotiation of contracts or the imposition and extension of duties on solar PV imports. The increased interest in the first half of 2020 may have been due to greater innovation in tenders or measures such as granting letters of credit.

Figure 4.19 ▷ Equity expected returns by level of tender competition for utility-scale solar PV, 2019-H1 2020

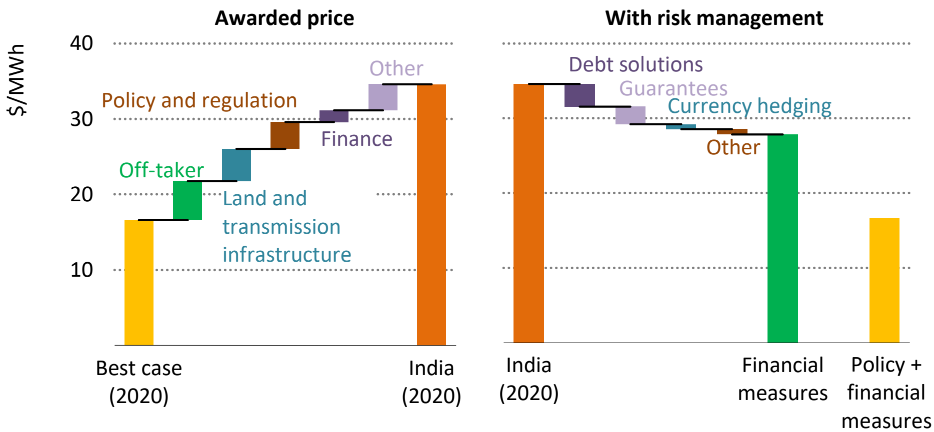


EIRR expectations for solar PV projects stood at around 15% over the course of 2019 and the first half of 2020, with differences depending on off-taker risks and type of site.

While developments over the past few years point to the ongoing maturity and improved competitiveness of the Indian renewables industry, the scaling-up of investment would be materially assisted by efforts to address persistent risks so as to bring generation costs more in line with global best case benchmarks. In the first half of 2020, the average price of tendered solar PV (weighted by capacity) was twice that of the best levels achieved in Europe.

In a survey of key investors, financiers and analysts, the key differences identified related to risks around power purchase (delays in payment by off-takers); contract renegotiation (off-takers seeking to renegotiate PPAs); land acquisition (concerns around availability, pricing, permitting and ownership); finance (limited availability of long-term, fixed-rate debt, and high cost); and regulatory uncertainty (lack of clarity in some laws and regulations, and fear of changes). Power purchase and renegotiation risks – both part of the off-taker risk category – are most prominent when the counterparty is a state discom with a weak financial and operational performance. The availability of grid connections and equipment supply chains are also important factors (Figure 4.20).

Figure 4.20 ▷ Awarded prices in new utility-scale solar PV tenders in India versus benchmark by risks (left) and financial measures (right)



Off-taker risks are the most significant perceived risks for solar PV projects in India today; policy reforms, debt solutions and guarantees could help address these risks.

Note: Awarded prices in India correspond to the average price discovered in solar PV tenders in the first half of 2020 (weighted by capacity). The best case corresponds to average prices discovered in solar PV tenders in Portugal and Spain over the period. Guarantees refer to financial guarantees provided by third parties.

Policy efforts are now being made to address issues around grid integration, land acquisition and the promotion of domestic manufacturing. Reaching the 450 GW target by 2030 will require a much more flexible system, with increased investments in grids and storage, a stronger focus on demand-side measures, and tenders that provide appropriate compensation for flexibility services provided to the system. Around 60% of the projects awarded in the first half of 2020 incorporate new arrangements, for example by allowing hybrid wind and solar PV, or projects bundled with domestic solar PV manufacturing capacity. SECI, a central government counterparty, has also introduced tenders with storage.

New business models and progress in other renewable segments may also improve risk-return propositions, but this too depends on ongoing reforms. Although around 90% of today's power supply is delivered through bilateral long-term contracts (IEA, 2020c), Indian authorities are discussing ways of expanding a wholesale market for trading power across India, including least-cost dispatch of electricity, which could lead to projects taking on a higher degree of merchant risk. Globally, a number of corporations contract power directly