Air Quality and Climate Policy Integration in India

Frameworks to deliver co-benefits

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Abstract

Air pollution has emerged as one of India's gravest social and environmental problems in recent years. At the same time, the country is experiencing signs of a warming climate with potentially devastating effects in the long term. Energy-related fuel combustion is at the heart of both crises. It is a main source of three major air pollutants, NO_X, SO_2 and $PM_{2.5,}$ and the largest contributor to India's CO_2 emissions. In many locations, concentrations of particulate matter persistently exceed recommended national and international standards with severe implications for public health. In 2019 alone, India experienced an estimated 1.2 million air pollution-related premature deaths. At the same time, India's growing economy is driving CO_2 emissions, which increased by more than 55% in the last decade, and are expected to rise by 50% to 2040. Today's energy choices matter for future development, as they have direct and far-reaching implications for the lives of a growing population. Energy-related air pollutants and CO_2 emissions often arise from the same sources, therefore the adoption of an integrated approach to tackle both can deliver important co-benefits. This report shows that well designed, coherent policy packages can deliver such synergies if properly implemented. In order to demonstrate co-benefit potential, it provides quantitative analysis that presents the ways in which flagship energy policies can contribute to both air pollution reduction and climate change mitigation in tandem. Four key sectors are assessed for this purpose: captive power plants, industrial energy efficiency, road transport electrification and expanded access to clean cooking. Policy frameworks that accommodate these synergies will provide a more impactful response and deliver durable benefits to the most pressing national health and environmental challenges, while offering great potential for India's contribution in the global fight against climate change.

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Executive summary

Energy is at the centre of India's environmental challenges

Air pollution has emerged as one of India's gravest environmental problems in recent years. In many locations, concentrations of particulate matter considerably exceed recommended national and international standards resulting in severe implications for population health. In 2019 alone, India experienced an estimated 1.2 million air pollution-related premature deaths.

Energy use is at the heart of India's air pollution and climate change challenges and today's energy choices matter for future development, as they have direct and far-reaching implications for the lives of a growing and rapidly urbanising population. In the IEA Stated Policies Scenario, which reflects the impact of existing and today's announced policy frameworks, India accounts for nearly one-quarter of global energy demand growth to 2040, more than any other country over the same period. While enhancing economic prosperity, India's increased energy requirements would entail substantial negative environmental externalities: in the coming years, India will become the largest contributor to global CO_2 emissions growth. Addressing air pollution and curbing CO_2 emissions in a timely and efficient way is vital for future, owing to its close linkage with socioeconomic and human development.

Policy integration and alignment is needed to boost India's clean energy transition

Given the complex nature of clean energy transitions, coherent policy packages are needed to deliver the necessary rate of change across the entire energy system. Energy-related air pollutant and CO_2 emissions arise from the same sources. Thus, if well designed, energy policies that seek to tackle air pollution or climate change can deliver important co-benefits for other targets.

Here, timing and technological choices are crucial for making measures such as renewables deployment, enhanced emissions standards, energy efficiency measures in industry and the thermal power segment, as well as residential clean energy access a consistent policy framework, fostering clean energy transition. While air pollution measures enable short-term CO_2 emissions stabilisation, climate policies prevent long-term technology lock-in and deliver lasting air pollution reductions. A power sector transition from fossil to renewable energy, for example, addresses both concerns and deliver significant air pollution and CO_2 emissions reductions. To demonstrate co-benefit potential, this report provides quantitative analysis on how flagship energy policies' contribute to both air pollution reduction and climate change mitigation. Four key sectors are assessed: captive power plants, industrial energy efficiency, electrification of road transport and expanded access to clean cooking.

Well-aligned air quality and climate policies generate co-benefits across the entire energy sector

In the power sector, IEA analysis finds that a timely and full implementation of the 2015 emissions standards notification for thermal power plants is crucial if India is to reduce air pollutants in the short term. The installation of emissions control technologies in thermal power plants would enable a 95% reduction in combustion-related emissions of SO_2 and an 80% reduction in $PM_{2.5}$ emissions from the power sector by 2030 compared to 2019 levels. Strong renewables deployment could further abate air pollutants and mitigate CO_2 emissions in the long-run.

Captive power plants, also known as auto-producers, are employed by heavy industry and service companies to generate electricity in the face of concerns regarding cost and reliability of grid supply. This fossil-fuel intensive sector is understood to make up around 14% of India's power supply in 2019, and with its greater share of coal and oil use, accounted for 16-18% of all power-related CO_2 and air pollution emissions. To meet India's decarbonisation targets, the power sector is expected to shift away from coal towards cleaner sources of power. While the government has introduced stricter pollution limits, the majority of thermal power plants are unlikely to meet the air pollution standards by the mid-2020s.

Even if the captive power sector continues to rely on coal at 2019 levels (87%), full implementation of emission control measures until 2030 would result in significant reductions of SO_2, NO_X and $PM_{2.5}$ emissions by 2040, despite strong growth in generation. Should solar PV provide one-third of captive power supply in 2040, similar to its share in the national mix if current targets are met, $PM_{2.5}$ and NO_X emissions would be reduced by another half. Failing to implement air pollution control technologies, however, would see emissions across all air pollutants more than doubling and SO_2 emissions reaching more than 1.5 Mt in 2040, a level 16 times higher than under the implementation of emission control measures. Given its scale and strong reliance on fossil fuels, the captive power segment must be included in all power-sector policy decisions if India seeks to accomplish both a power sector transition and industrial development.

Supported by a range of economic development policies, the contribution of industry to gross domestic product nearly quadrupled over the past two decades resulting in significant energy demand growth in the sector. By 2019, industry was India’s main energy-consuming sector, accounting for more than one-third of total final energy consumption, with three sectors, iron and steel, chemicals and cement accounting for almost 45%. IEA projects that strong growth in economic output could more than double industry energy demand by 2040, increasing the sector’s share of final energy consumption to 40%.

India’s Bureau of Energy Efficiency estimates that the industry sector could contribute 60% of possible energy savings until 2031 and several programmes have been introduced to meet this target. The Perform, Achieve and Trade (PAT) scheme is the cornerstone of these efforts. Established in 2012, the first PAT cycle targeted large energy-intensive industries. Following initial success, the scheme was extended, and phases PAT II-VI have been rolled out annually in two-year cycles since 2016. By improving energy efficiency and avoiding additional energy consumption in industry, the PAT scheme indirectly delivers environmental benefits as lower energy consumption results in fewer CO_2 and air pollutant emissions. Nonetheless, it could be argued that the PAT scheme was not ambitious enough and targets could be set higher, such as by means of benchmark setting as well as broader coverage of large energy consumers and sectors.

IEA analysis estimates that a continued and expanded PAT scheme could result in more than 80 Mt of avoided CO_2 emissions in 2030 and 265 Mt CO_2 in 2040, of which iron and steel would contribute about 70% and cement more than a quarter. Converting the PAT scheme’s energy saving to carbon saving certificates could further trigger fuel switching, which would contribute additional CO_2 emissions. Furthermore, expanding the PAT scheme could save more than 10% SO_2 and NO_X pollution from large industry by 2040.

The past two decades have seen seven-fold increase in the number of passenger cars on India’s roads leading to significant increases in urban air pollution levels and associated health problems. In response, India has adopted tighter emissions standards (Bharat Stage VI) effective for all vehicles manufactured after March 2020 and introduced the ambition to electrify 30% of the road transport fleet by 3020.

In terms of air pollution, road transportation was responsible for more than 44% of total NO_X emissions (3.3 Mt) and around 7% combustion-related $PM_{2.5}$ emissions in 2019. Implementing existing policies, including stricter fuel and vehicle standards, could lead to road transport-related NO_X emissions peaking around 2025 and then declining by over 60% by 2040. This would reduce road transport's share of combustion-related NO_X emissions to one-quarter by 2040. India's transport sector directly emitted almost 320 Mt CO_2 in 2019 or 14% of the country's carbon emissions, more than 90% of which arose from road transport.

Growing demand for road transport sees projected emissions from the sector rising to more than 450 Mt CO_2 by 2030, and almost 600 Mt CO_2 by 2040. Furthermore, the growing use of EVs leads to indirect emissions in the power sector. While these emissions amounted to less than 0.5 Mt CO_2 in 2019, their importance is expected to grow with the uptake of EVs. By 2030, CO_2 emitted by EV electricity consumption could reach 20 Mt CO_2, and more than double by 2040. The speed at which the power sector reduces its CO_2 intensity is closely related to the net mitigation potential of large-scale EV deployment. A power mix that remains as carbon-intensive in 2040 as it was in 2019 could lead to the EV fleet emitting 20Mt CO_2 more than an equivalent fleet of conventional cars, while decarbonising the power mix as currently planned could deliver savings of more than 35 Mt CO_2.

Around 660 million people, just under half of India's population, relied primarily on traditional use of biomass for cooking and heating in 2019. Burned indoors in poorly ventilated spaces, these fuels directly expose households to indoor air pollution, often with severe consequences for their health. A quarter of the almost 2.5 million premature death cases resulting from indoor air pollution globally occurred in India. Over the past decade, the country developed a comprehensive policy framework to promote clean cooking solutions notably targeting poor, rural households resulting in the share of the population relying on biomass, kerosene or coal declining by almost 20% over the period 2010-19, with half of the total population using cleaner fuels such as LPG.

Heavy reliance on traditional biomass for cooking and heating results in high levels of harmful $PM_{2.5}$ pollution and to a lesser extent contributes to NO_X and SO_2 emissions. Indoor air pollution occurs disproportionately in rural areas, where more than 90% of the population live without access to clean cooking. Stated policy efforts to improve access to clean cooking fuel are expected to reduce the share of the population using traditional biomass to less than 25% and enable a 40% reduction in indoor particulate matter air pollution by 2040. Replacing traditional biomass with LPG would increase CO_2, but reduce methane emissions and could avoid a substantial amount of black carbon, a potent carbon forcer. Nonetheless, the high inequality in geographical distribution would remain, with 95% of India's population without clean cooking access living in rural areas in the future.

Fully shifting away from highly polluting to clean cooking fuels by 2030 would almost entirely remove indoor $PM_{2.5}$ emissions and reduce associated premature deaths to 0.1 million cases annually. Efforts to increase the availability and affordability of LPG in rural areas are needed along with improved gas stove availability and gas distribution infrastructure in urban areas. In major cities, overcoming reliability issues and improving the wattage of supply through investments in the power distribution infrastructure would allow electricity to actively contribute to clean cooking access in high- and middle-income urban areas. Finally, regional diversity will require policy makers to understand and account for geographic and cultural differences or similarities, and design solutions to improve access to cooking energy accordingly.

Ways forward

Present analysis of India's energy and climate policies shows that current air pollution and climate measures, if fully implemented, could improve air quality but remain insufficient to deliver the levels recommended by the World Health Organisation. A wholly integrated policy response could enable additional, technical savings of 3.2 Mt SO_2, 5.1 Mt NO_X and 4.2 Mt $PM_{2.5}$ in 2040, of which more than two-thirds would be realised by stricter air pollution measures. Policy makers must recognise that in many sectors, there are synergies between air pollution and climate policy objectives. Otherwise, benefits from both air pollution and climate policy measures will be undervalued. Acknowledging these synergies in the design and implementation of future policy frameworks will provide a more impactful response to the most pressing national health and environmental challenges and offer great potential for India's contribution in the global fight against climate change.

Introduction

The purpose of this report is to assess how an integrated policy response to the challenges facing India's clean-energy transition would result in multiple benefits for the country. It also provides insights to support policy implementation. In doing so, this report aims to demonstrate that enhancing the synergies between air pollution and climate policy objectives can provide an efficient means to achieve both.

IEA analysis shows that efforts to reduce air pollution in India can be reinforced by policies that promote energy access and CO_2 emissions reductions, alongside measures to make an integrated response more impactful. The uptake of low-carbon energy technologies can lead to substantial reductions in emissions of air pollutants that are otherwise difficult to address by means of air pollution policies alone. Moreover, air pollution policies that target energy access and GHG emissions can also deliver lasting reductions in air pollutant emissions by tackling the causes of air pollution, not merely by introducing technology to reduce it. To demonstrate the importance of timing and synchronisation of policies, this report provides quantitative analysis of challenges in several sectors.

Need for policy integration and alignment

Given the complex nature of energy transitions, coherent policy packages are needed to deliver the necessary rate of change across the energy system. One approach to make this politically feasible, as well as cost-effective, is to seek out integrated policy approaches and synergies that simultaneously satisfy goals such as enhanced energy security and affordability along with air pollutant and greenhouse gas (GHG) emissions reductions.

The choice of policy instrument to tackle air pollution can also have important implications for CO_2 emissions. An exclusive focus on direct emissions controls (e.g. end-of-pipe technologies), for example, rather than a more balanced package of measures, could result in investments being directed to carbon-intensive energy infrastructure, such as coal-fired power plants or internal combustion engines, instead of low carbon technologies. The inverse also applies measures that address climate change, adopted in isolation from the aims of air pollution abatement, could inadvertently lead to more air pollution.

Highlighting synergies, IEA analysis for India illustrates the benefits of an integrated approach to reducing air pollutant and CO_2 emissions. For example, investment in energy efficiency and renewable energy is an effective low-carbon transition strategy resulting in less fuel combustion. Equally, achieving universal access to clean cooking by reducing, and eventually eliminating, the use of solid fuels, such as traditional biomass, substantially reduces emissions of $PM_{2.5}$. This is an important element to ensure universal access to affordable, reliable and modern energy services by 2030 (Sustainable Development Goal 7.2).

Two areas that demonstrate clear cross-benefit for air quality and climate change are actions to reduce black carbon (soot), a major component of PM, and methane emissions. Black carbon emissions resulting from incomplete combustion, particularly from household biomass stoves and diesel vehicles, affects the climate in multiple ways: it absorbs incoming sunlight, leading to atmospheric warming; and it settles on the ground, accelerating the melting of polar and alpine ice.

Table 1.1 Air pollution and climate change mitigation technology double wins

Sector	Technology	Benefits
Power	Renewables deployment and air pollution control measures.	Reduced SO_2, NO_X, PM and CO_2 emissions.
Transport	Road transport electrification and vehicle emission standards.	Reduced NO_X, PM and CO_2 emissions.
Residential Buildings	Enhanced use of clean fuels, mainly LPG and PNG, for cooking.	Reduction of indoor air pollution; $PM_{2.5}$, including BC emissions.
Industry	Increased energy efficiency, electricity from renewables, and air pollution control measures.	Reduced SO_2, NO_X, PM and CO_2 emissions.

An analysis of India's energy and climate policies shows that current air pollution and climate measures, if fully implemented, could improve air quality but remain insufficient to deliver the levels recommended by the World Health Organisation. Air pollutants and GHGs arise from the same sources in the energy sector, therefore, an integrated policy approach can deliver useful synergies. Air pollution measures can contribute towards both short-term GHG emissions stabilisation and an early peak in global GHG emissions. Conversely, climate policies can prevent long-term technology lock-in and deliver lasting air pollution reductions. A power sector transition from fossil to renewable energy, for example, can address both concerns while delivering significant air pollution and GHG emissions reductions.

Underlying policy, data and modelling

The analysis in this report draws upon IEA historical data and statistics. The projections used are those in the World Energy Outlook (WEO) 2020. Data for energy activity and carbon dioxide are IEA modelling outputs. Air pollutant emissions, corresponding emissions factors and related health impacts are provided by the International Institute of Applied Systems Analysis (IIASA). For this purpose, the IEA World Energy Model (WEM) and IIASA's Greenhouse Gas - Air Pollution Interactions and Synergies (GAINS) model have been coupled to derive insights into air pollution trends on the basis of WEO projections for energy sector developments. Furthermore, The Energy and Resources Institute (TERI) provided modelling of air pollution concentrations based on the IEA Stated Policies Scenario (STEPS). IEA assumptions in the STEPS were based in part on official data and policy announcements from the Government of India (Box 1.1).

Box 1.1 Stated Policies Scenario (STEPS)

The IEA's Stated Policies Scenario (STEPS) analyses plans from today's policy makers and illustrates their consequences for energy use and air pollutant and GHG emissions. The aim of the STEPS is to provide a detailed sense of the direction in which existing policy frameworks and today's policy ambitions can take the energy sector out to 2040.

Policies assessed in the STEPS cover a broad spectrum, including Nationally Determined Contributions under the Paris Agreement and others. In practice, the bottom-up modelling effort in the scenario requires more sectoral level detail, such as pricing policies, efficiency standards and schemes, electrification programmes and specific infrastructure projects.

Government announced policy plans include some far-reaching targets, such as aspirations to achieve full energy access within a few years, the reformation of pricing regimes and, more recently, to attain net zero emissions for some countries and sectors. As with all policies considered in the Stated Policies Scenario, these ambitions are not automatically incorporated into the scenario: full implementation cannot be assumed, so the prospects and timing for their realisation have been based upon our careful assessment of countries' relevant regulatory, market, infrastructure and financial circumstances.

An inventory of the key policy assumptions available, along with all the underlying data on population, economic growth, resources, technology costs and fossil fuel prices, are available in the introduction to the World Energy Model: IEA Stated Policies Scenario.

Report structure

This report is organised into two sections. The first section (Chapter 1) lays out the conceptual framework that illustrate synergies between air pollution and climate change mitigation policy. It provides an integrated outlook for both air quality and climate, quantitatively illustrating those technological double wins across key energy sectors. The second section is split into four chapters (Chapters 2-5), each of which explores in detail the potential for air quality and climate co-benefits from policy integration for one key challenge in different energy-related sectors. These challenges were chosen to develop broader insights on energy, environment and socio-economic policy integration.

- Chapter 2 explores the impact of captive power generation on industrial sector transformation: synergies between industrial development, air pollution and power sector transition.
- Chapter 3 explores transport electrification and clean energy transition: synergies between greater use of electricity in transport and power sector transition.
- Chapter 4 examines clean cooking air pollution and climate co-benefits: synergies between policies to improve access to clean cooking and delivering air-pollution and GHG emissions reductions.
- Chapter 5 examines energy efficiency air pollution and climate co-benefits: synergies between policies to improve industrial energy efficiency and delivering air pollution and GHG emissions reductions.

Chapter 1. Air quality and climate co-benefits from policy integration

Air pollution and climate technology policy synergies

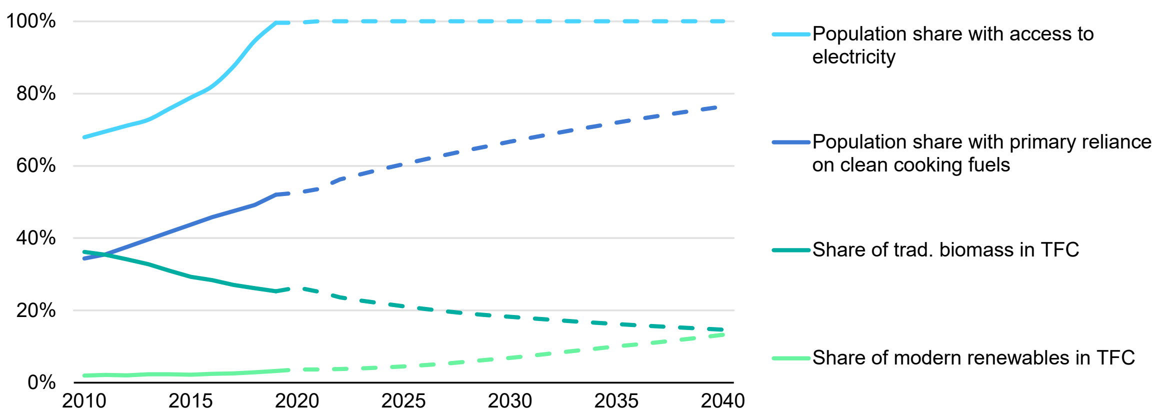
Air pollution has emerged as one of India's gravest environmental problems in recent years, and energy use is at the heart of it. Addressing this problem is vital for the Government of India (GoI) owing to its close association with socioeconomic and human development. Improvements in air quality contribute to the achievement of multiple United Nations Sustainable Development Goals (UN SDGs): household air pollution can be reduced through enhanced clean energy access (SDG 7.1); an increase in the share of renewable energy (SDG 7.2) and enhanced energy efficiency (SDG 7.3) can mitigate air pollution from the power and industrial sector; and overall air quality in cities (SDG 11.6) can improve with increased access to sustainable transport (SDG 11.2). Finally, measures to abate air pollution also reduce GHG emission (SDG 13). The imperative to improve air quality is therefore a strong motivation for action that also benefits the climate.

The most significant energy sector actions announced by the Government of India (GoI) to improve air quality are plans to invest in renewable energy, promote energy efficiency and improve energy access. Renewable energy and energy efficiency expansion avoids further fossil fuels consumption growth and will result in lower combustion in the future, both improving air quality and mitigating CO_2 emissions. The transition from polluting fuels to clean energy technologies provides precisely this type of win-win for air quality and climate change, with major cuts in key energy-related pollutants occurring together with reductions in energy-related CO_2 emissions. It is an immense challenge to chart a course towards achieving all of India's SDGs in parallel. There remains a risk that progress in one area could hamper efforts elsewhere. Optimising technology choices can significantly avoid or minimise trade-offs to the extent possible, and alignment of relevant policies will help to ensure that synergies and co-benefits of measures in one area can boost or support other goals.

Trends and outlook for GHG emissions and air pollution

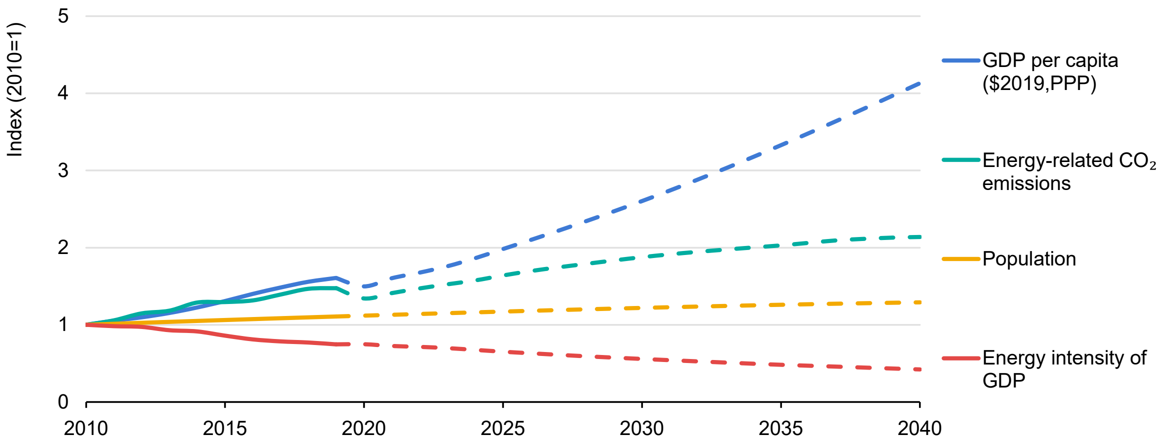
In recent years, India has made significant progress towards implementing energy policies that achieve the UN SDGs. India successfully provided electricity access to nearly its entire population and has enhanced the share of population with access to clean cooking fuels from one-third in 2010 to more than 50% in 2019 (SDG 7.1). It gradually increased the share of modern renewables and strengthened its policies to reduce air pollution (SDG 3) (Figure 1.1).

Figure 1.1 Share of renewables in final energy demand and population with access to clean energy sources in the Stated Policies Scenario, 2010-2040,



Between 2010 and 2019, India experienced strong economic growth, raising the GDP per capita by 60% and increasing the country's total energy consumption by one-third. As India's energy sector is fossil fuel intensive, CO_2 emissions increased by nearly 50% over the same period, despite noted improvements to CO_2 and GDP energy-intensity. In the coming decades, further economic development and a growing, rapidly urbanising population are projected to further boost energy demand. In the IEA Stated Policies Scenario (STEPS), India's population grows by 17%, and GDP per capita increases more than 2.5 times between 2019 and 2040. Although the economy's energy intensity improves slightly, energy-related CO_2 emissions increase by 45% by 2040, making the road to fully achieving the SDGs challenging (Figure 1.2).

Figure 1.2 Key indicators of economic development and emissions in the Stated Policies Scenario, 2010-2040



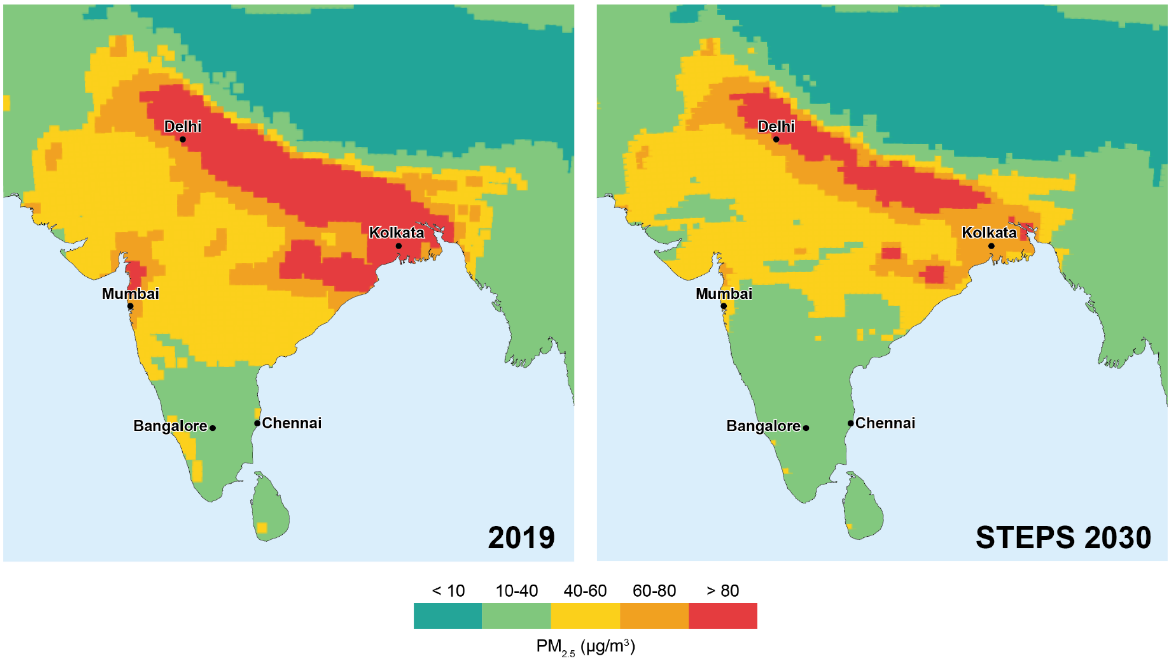
Air pollution is one of India's most pressing challenges

Air pollution has emerged as one of India's gravest environmental problems and energy-related activities are at its heart. It is a main concern for public health: in 2019, nearly 1.2 million premature deaths could be attributed to ambient and household air pollution, accounting for more than one-fifth of the global total. Curbing air pollution-related deaths is a key policy priority for the GoI.

India suffers from extremely high levels of air pollutant concentrations. Six of the ten most polluted cities globally in 2020 were in India. The Central Pollution Control Board (CPCB) and the National Green Tribunal have identified 124 cities in 24 of India's 36 states and union territories as "non-attainment cities" for exceeding the pollutant levels set under the National Ambient Air Quality Standards (NAAQS), 2009.[1] In 2019, nearly half of India's population lived in areas that experience fewer than seven months a year of PM concentrations that fall below the CPCB's safe limit of 60 μg/m^3 for 24 hours, or so-called *clean air days*. About 70% of the country exceeded the recommended national annual average concentration level of 40 μg/m^3 of $PM_{2.5}$,[2] and almost one-fifth experienced levels over 80 μg/m^3 in 2019 (Figure 1.3).

[1] NAAQS issued in 2009 by the CPCB require for PM_{10}, 60 μg/m^3 annually and 100 μg/m^3 over 24 hours; $PM_{2.5}$, 40 μg/m^3 annually and 60 μg/m^3 over 24 hours; for NO_2, 40 μg/m^3 annually and 80 μg/m^3 over 24 hours; for SO_2, 50 μg/m^3 annually and 80 μg/m^3 over 24 hours.
[2] The World Health Organization recommends a $PM_{2.5}$ level of 10 μg/m^3 as annual average.

Figure 1.3 Average annual $PM_{2.5}$ concentration levels in India in the Stated Policies Scenario, 2019 and 2030

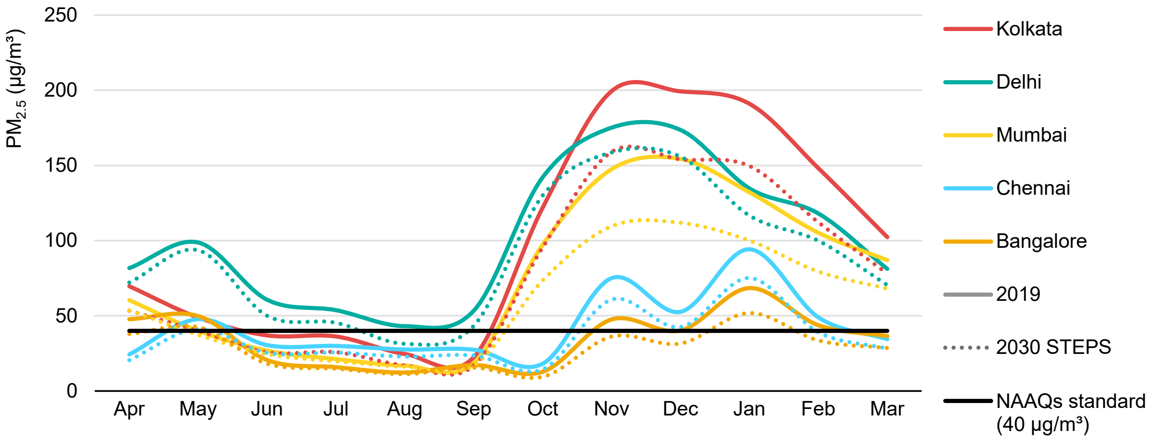


Note: this map included herein, are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
Source: TERI and IEA analysis.

While India's air pollution is perennial and affects the entire country, northern states suffer more acutely in winter. Lower temperatures and the northern region's geographical and meteorological conditions contribute substantially to extremely high $PM_{2.5}$ concentration levels, but pollution sources are anthropogenic. Although energy-related activities are responsible for a large share, other sources, such as the burning of crop residues in late autumn, are also a source of PM emissions in these regions. Northern urban agglomerations such as Kolkata, Ghaziabad or Patna meet the recommended 40 µg/m^3 of $PM_{2.5}$ only during the summer but show concentration levels of more than 150 µg/m^3 in the winter. Air pollution concentrations in the capital region around Delhi never fall below 40 µg/m^3 throughout the year. In contrast, southern cities such as Chennai and Bangalore show less variability year-round, with an annual average of 35-40 µg/m^3 (Figure 1.4).

India's Covid-19 related lockdowns gave a glimpse of life with high urban air quality. During the six-week lockdown that started in late March 2020, $PM_{2.5}$ levels were nearly 60% lower in Delhi, 45% lower in Bangalore and 30% lower in Chennai than during the same period in the previous year owing to reduced industrial and transport activities. Similar steep drops were observed in various Indian cities and for all key air pollutants, including SO_2, NO_X and CO.

Figure 1.4 Monthly $PM_{2.5}$ concentration in specific cities in the Stated Policies Scenario, 2019 and 2030

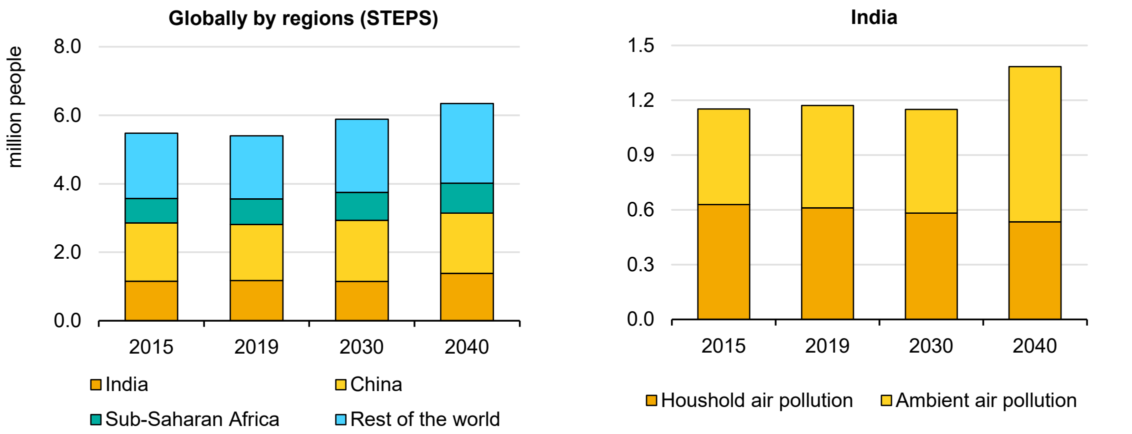


Source: TERI and IEA analysis.

The GoI's National Clean Air Programme (NCAP) aims to lower PM concentrations by 20-30% by 2024 compared to 2017 levels. While a reduction of this scale will not necessarily ensure that cities meet the standards under NAAQS, this is the first time that an air quality improvement target has been given a specific delivery date. Even if all planned polices are implemented, overall air quality might only improve slightly. More than 50% of India could still experience $PM_{2.5}$ concentrations above 40 µg/m^3 by 2030 and continue doing so until 2040. However, the number of locations in which levels exceed 80 µg/m^3 could halve to less than 10% of the country by 2030, decreasing to 7% in 2040. Air quality in cities could improve, with annual $PM_{2.5}$ concentrations in urban areas falling on average by nearly 20% in the next decade.

As a result, annual premature deaths related to air pollution are expected under current and planned policies to decrease only slightly by 20 000 in 2030 and then continue to increase until 2040. While pollution reduction measures benefit air quality, a growing, but on average ageing and rapidly urbanising population means that more people are exposed to higher air pollution levels from industry and traffic, resulting by 2040 in almost 1.4 million premature death cases of which 60% are related to ambient air pollution (Figure 1.5).

Figure 1.5 Premature deaths related to air pollution in the Stated Policies Scenario, 2015-2040



Source: IIASA and IEA analysis.

Sectoral breakdown of air pollutant and GHG emissions

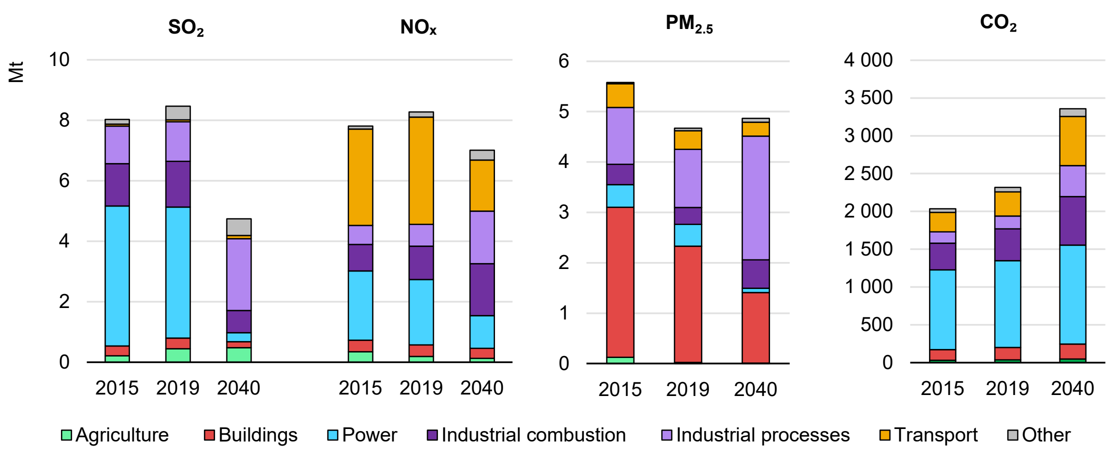
In the future, India's growing, urbanising, and on average, richer population translates into a higher demand for housing, transport infrastructure and electricity consumption. These key drivers of energy demand, along with industrial growth, would lead to growth in air pollutant and CO_2 emissions. The IEA estimates that India's energy sector alone accounted for almost three-quarter of the country's GHG emissions in 2015. Further, it is the largest contributor towards three major air pollutants: NO_X, SO_2 and $PM_{2.5}$ and therefore the key component to solve India's air pollution crisis (Figure 1.6).

NO_X primarily stems from oil combustion in the transport sector and thermal power plants, which account for approximately 40% and 25% of India's NO_X emissions, respectively. India is the world's largest emitter of SO_2, contributing more than one-fifth of the global total in 2019, substantially more than the second-ranked country, the Russian Federation (12%). Half of India's SO_2 emissions arise from thermal power plants and industrial activities add another third. Both power and industrial plants are typically clustered around urban areas, making NO_X and SO_2 emissions a more serious challenge to densely populated regions. In addition, NO_X and SO_2 travel by air and can transform into fine particulate matter within one week, further contributing to high levels of $PM_{2.5}$ concentrations.

Incomplete traditional biomass burning in buildings was responsible for nearly half of India's direct $PM_{2.5}$ emissions in 2019, while fossil fuel combustion in industry sectors and industrial processes added more than 30%. Contributions to total emissions differ significantly across states. India's most populous state, Uttar

Pradesh, accounted for 14% of $PM_{2.5}$ emissions in 2015, largely stemming from residential traditional biomass combustion, while Maharashtra emitted 12% of the national SO_2 and 10% of NO_X pollution owing to its high thermal power capacity on-road vehicle density. In addition, non-energy-related sources, such as dust from construction of buildings or roads as well as residues from crop burning in late autumn are a significant source of PM emissions in certain regions. Furthermore, India's heavily fossil fuel-reliant energy sector released more than 2.3 Mt CO_2 in 2019, with coal the largest energy source in both power generation and industry, accounting for nearly 70%. Covid-19 related lockdowns brought India's economy to a standstill, reflecting in a 7% (or 160 Mt CO_2) decline in 2020 CO_2 emissions compared to the previous year.

Figure 1.6 Air pollutant and CO_2 emissions by sector in the Stated Policies Scenario, 2015, 2019 and 2040



Note: The presented data does not include non-energy emissions sources (e.g., crop burning).
Source: IIASA and IEA analysis.

Successful implementation of the GoI's stated policies is essential to keep air pollutant emissions growth in check. By 2040, national SO_2 emissions could be reduced by nearly 45% through a full desulphurisation of thermal power, while NO_X pollution could decrease by 15% through emissions abatement in the transport sector. Only $PM_{2.5}$ is expected to slightly increase by 4% as emissions from industrial processes double until 2040 (Figure 1.6).

Without stringent implementation of air pollution policy measures, combustion-related SO_2 emissions would almost double between 2019 and 2040, roughly reaching a level 10 times higher than in the STEPS. NO_X pollution could increase fivefold and $PM_{2.5}$ by nearly 50% over the same period.

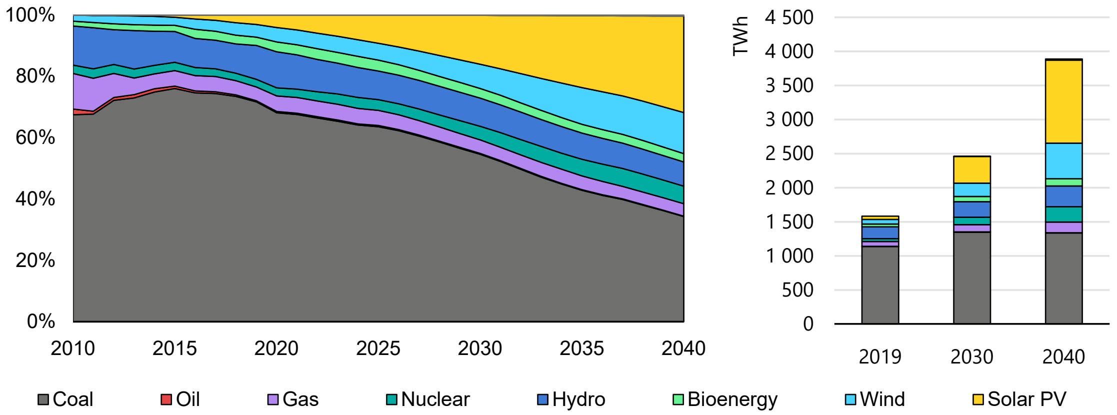
Sector-specific air pollution and climate co-benefits

Four areas are explored in this report to further understand how air quality and climate objectives align, and the importance of policies to ensure objectives are met and co-benefits achieved. The four are: captive power plants (power generation), road transport electrification, clean cooking and industrial energy efficiency. These policy-integration focus areas vary in terms of data gaps and the degree to which quantified analysis can therefore illustrate potentials and trade-offs, but in all cases, they illustrate the importance of policy alignment and being adequately sequenced. Certain policies appear particularly important as a basis to meet more than one policy objective, such as implementing pollution control measures in thermal plants. An overview of each of the four areas is presented below.

Captive power plants may be a "blind spot" within the electricity generation sector

India's power sector made up half of the 8.5 Mt of total SO_2 emissions in 2019, with industrial activities contributing an additional one-third. Coal combustion was the primary driver of SO_2 emissions, fuelling nearly 80% of India's 2019 electricity generation and about 45% of industrial production. Air pollution control technologies for thermal power plants, such as flue gas desulphurisation, remain time-consuming and expensive to install, especially when used to retrofit older plants, and are therefore rarely deployed. To address this situation, India's government amended the Environment (Protection) Act Rules (1986) in 2015, tightening emissions standards for $PM_{2.5}$, NO_X and SO_2. India's power sector is also the country's largest CO_2 emitter. Electricity carbon intensity declined by 7% between 2015 and 2019 thanks to more renewable energy sources and installation of a suite of new plants that improved thermal power efficiency. Nonetheless, coal's continuing dominance in India's power generation mix still gave the country a relatively high carbon intensity of 725 g CO_2/kWh in 2019 (Figure 1.7).

Figure 1.7 Electricity generation by fuel in India in the Stated Policies Scenario, 2010-2040



Addressing coal power emissions from both an air quality and climate perspective can maximise benefits through joint and well-synchronised enhancement of air pollution standards and a shift to renewable energy. A 90% reduction of power-related SO_2 emissions between 2019 and 2040 is possible, and would lead to a reduction in total, energy-related SO_2 emissions by 45%. In addition, power related NO_X emissions could drop by 50% in the same period. This development depends upon full implementation of the revised emissions standards (2015) alongside a diversification of the power mix towards renewable energy sources, implying that most coal-fired capacity must be fitted with advanced air pollution control technology by the mid-2020s.

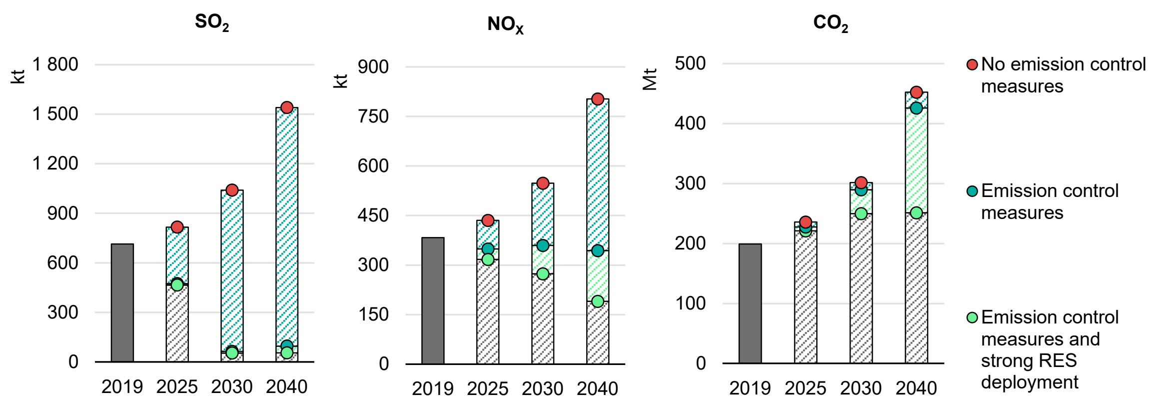
This drastic reduction of power-sector air pollution takes place against a backdrop of an increase in coal-fired generation by nearly one-fifth between 2019 and 2040 per STEPS. As power plants are often located near populated areas, the implementation of stricter environmental regulation could have significant positive impact on population health. There are, therefore, considerable potential benefits to resolving problems related to any delay in compliance with 2015 emissions standard notification.

While enhancing the compliance to air pollution standards will be important, rapid expansion of modern renewables, specifically solar PV and wind power-underpinned by ambitious policy support, are crucial measures towards pollution-free power that simultaneously reduce GHG emissions. In the STEPS, coal remains the primary source of electricity generation until 2040. Its share falls in the scenario from greater than 70% in 2019 to 55% in 2030, and to nearly one-third in 2040 as renewables expand from one-fifth in 2019 to 55% in 2040. This results in a 54% reduction of electricity's carbon intensity to approximately 335 g CO_2/kWh in 2040. Despite its falling share, increased coal power generation is the reason why power-related CO_2 emissions rise until 2030 to 1.3 Gt CO_2 and plateau thereafter. In this regard, linking air quality with decarbonisation policy also plays an important role in addressing the two challenges in a synchronised manner.

Policy Integration Focus: The role of captive power role in air quality and climate change.

Captive power plants (CPP) provided nearly 14% of India's electricity supply in 2019. CPPs are set up by industrial consumers to ensure a reliable and affordable electricity supply. In 2019, they contributed between 16-18% to total power-related CO_2 and air pollutant emissions, due a share of coal-fired electricity that is 15 percentage points higher than the national average. Coal-based power accounted for nearly all SO_2, 90% of $PM_{2.5}$ and 75% of NO_X emissions as well as 90% of CO_2 emissions from CPPs in 2019. Projections based on the current state and historical role of CPPs show that without emission control technology implementation in fossil plants or enhanced renewables deployment, the segment's annual emissions of CO_2, SO_2, NO_X and $PM_{2.5}$ could more than double until 2040 (Figure 1.8).

Figure 1.8 SO_2, NO_X and CO_2 emissions from captive power plants in 2019 and potential outlook 2025-2040



To effectively curb air pollutant and CO_2 emissions in the future, stringent climate and air quality policies implementation should not only be applicable to the national power sector, but specifically target CPPs. This is even more salient as India's government facilitates grid integration of captive plants while industrial electricity prices remain relatively high, which further incentivises their construction. As captive thermal plants are only governed since 2018 by the revised air pollutant emission standards from 2015, there is a risk of delayed implementation of air pollution controls by coal-fired CPPs.

In the short term, a strong increase in power-related air pollution can be avoided if coal-fired CPPs are equipped with air pollution control technologies. At the same time, India should tap its full solar PV potential to increase its share of renewables in the generation mix. A fuel switch towards renewable energy sources through ambitious deployment of solar PV could curb emissions to around 250 Mt CO_2 in 2040, nearly 45% lower than in a projected situation without actions to deploy low-carbon generation in the captive power segment.

Given high uncertainties regarding the true extent of India's captive fleet, in particular diesel generators with a capacity of < 1 MW, it remains essential to improve data quality by establishing a policy framework tailored to the captive segment's particularities and enable adequate monitoring.

Road transport electrification benefits tied to power sector policies

Transport was responsible for about 40% of India's NO_X emissions in 2019. Most transport related NO_X emissions stem from road vehicles; more than half from heavy-duty vehicles (HDVs)[3] only. Road transport activity increases with population density, and vehicle tail-pipe emissions occur close to the ground, lowering the pollution's dispersion. These features make urban NO_X pollution particularly unhealthy. While mass transport, such as buses and rail, are important mobility modes, India experiences greater individual motorisation. Individual motor ownership increases by a factor of five between 2019 and 2040 in the STEPS, underscoring the importance of advanced emission standards and alternative fuel use for all road transport vehicles.

Road transport NO_X emissions fall by 60% between 2019 and 2040 in the STEPS, with sector's share of NO_X emissions declining from 40% in 2019 to about 25% in 2040. The introduction of Bharat Stage (BS) VI emissions standards, which are mandatory for conventional internal combustion vehicles sold after April 2020, are

[3] Heavy-Duty Vehicles (HDVs) segment includes freight vehicles of more than 3.5 tonnes or passenger transport vehicles of more than 8 seats (buses and coaches). Light-Duty Vehicle(s) (LDVs) include passenger cars and vans.

expected to contribute to reducing air pollutant emissions despite the exponential growth in individual car ownership and mass road public transport, combined with continued reliance on road freight.

For sustained air pollution reduction, a much greater share of EVs and a considerable fuel economy improvement is required, which also has considerable climate co-benefits. The transport sector represented 14% of India's total CO_2 emissions in 2019. While this comparatively small share is expected to remain relatively stable, overall growth in transport activity translate to total sectoral emissions more than doubling by 2040 to reach 650 Mt CO_2. Road transport is almost solely responsible for the growth in transport emissions, and this is expected to remain true up to 2040. Given strong activity growth, total CO_2 emissions from passenger cars could more than triple between 2019 and 2040 in the STEPS, increasing their share in road transport CO_2 emissions from one-fifth in 2019 to nearly one-third in 2040; HDVs could add another 40% in 2040.

Road transport electrification offers a unique opportunity to reduce both air pollution in urban areas, addressing social and public health issues, and GHG emissions from road transport — specifically connected to targets for developing low-carbon power. The GoI stated the ambition to reach a 30%-share of EVs in total vehicle sales by 2030. India's flagship programme to promote EVs is Faster Adoption and Manufacturing of Electric Vehicles (FAME), which reduces the relatively higher upfront costs of EVs by providing extensive financial incentives to purchasers of electric and hybrid vehicles, mostly targeting two/three-wheelers and buses. In 2040, nearly 15% of the passenger cars and more than 50% of the two/three wheelers on India's roads are expected to be electric.

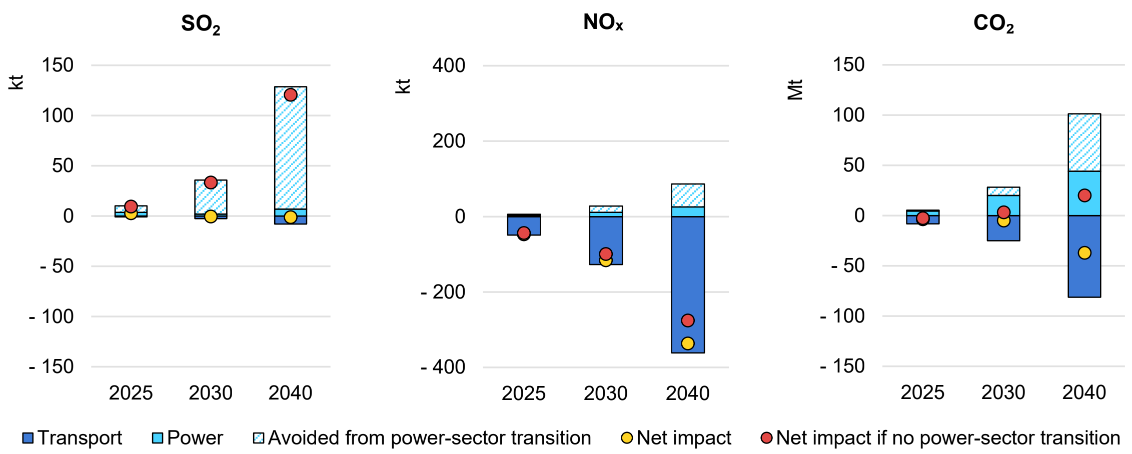
Policy Integration Focus: Transport electrification potentially doubles benefits for air pollution and GHG emissions

Increasing the stock of EVs rather than internal combustion engines (ICEs) shifts demand growth for transport fuel from oil to electricity. This immediately prevents a substantial amount of NO_X pollution: an EV can avoid roughly 12 times the NO_X emissions generated by a conventional car and thus improve ambient air quality.

A rapid expansion of the EV fleet also leads to a surge in electricity demand, causing additional indirect air pollutant and CO_2 emissions from the power sector. In 2019, India's EV fleet consumed only around 0.02% of total final electricity consumption, but in the STEPS this share reaches about 2% by 2030. Fuelling EVs with electricity generated in India's power sector in 2019, strongly relying on coal-fired power plants that largely do not comply with the revised emissions standards, 2015, still adds about 5 times more SO_2 than using a conventional car. Therefore, it is imperative to implement pollution controls that enable the coal-fired segment to comply with 2015 SO_2 emission standards to ensure that road transport electrification leads to a reduction in all air pollutants. A stringent power sector transition would allow EVs to emit more than 10% less SO_2 than a conventional car would. However, if full implementation of emissions control measures in India's coal-fired plants is delayed, the EV fleet's indirect SO_2 emissions could potentially reach a level 18 times higher in 2040 than if the measures were fully implemented.

In the STEPS, indirect carbon emissions from the expanded EVs fleet's electricity consumption amount to 20 Mt CO_2 in 2030 and more than double until 2040, by which time they would represent 7% of total road transport emissions. India's electricity emissions intensity needs to be less than 700-750 g CO_2/kWh for new electric passenger cars to result in fewer CO_2 emissions than a conventional passenger car. India's electricity emissions intensity is around this level today. In the STEPS, electricity's emissions intensity would fall to 340 g CO_2/kWh in 2040, allowing the expanded EV fleet to save more than 35 Mt CO_2 annually (Figure 1.9). The exact level of savings would, however, depends upon the precise time of vehicle charging, as electricity emissions intensity in 2040 in the STEPS varies considerably throughout the day.

Figure 1.9 Emissions of SO_2, NO_X and CO_2 from the use of EVs in the Stated Policies Scenario, 2025-2040



Road transport electrification offers a clear, unique opportunity to reduce both CO_2 and overall, in particular urban air pollution. The extent to which electrification reduces overall air pollutant levels and CO_2 emissions will depend upon shifting to a low-carbon power mix, as emissions from displaced oil consumption need to outweigh indirect electricity emissions.

Clean cooking reduces indoor air pollution, and climate impacts

Particulate matter (PM) emitted in residential buildings represented almost two-thirds of total combustion-related $PM_{2.5}$ emissions in India in 2019. This pollution largely stems from incomplete traditional biomass burning, such as fuelwood or agricultural residues, created by residential cooking and heating activities. In 2019, about half of the Indian population used solid, polluting fuels as their primary fuel for cooking; in rural areas, traditional biomass fuelled two-thirds of cooking activities. Policy efforts to promote access to clean cooking solutions led to a 25% decline in $PM_{2.5}$ emissions between 2015 and 2019 (to 2.2 Mt). The adverse consequences from the use of biomass for cooking fall predominately on women and children, who suffer the worst health effects from fuel wood gathering and smoky indoor environments. Kerosene lamps used for lighting also contribute to indoor air pollution, as their smoke contains high levels of $PM_{2.5}$, especially black carbon.

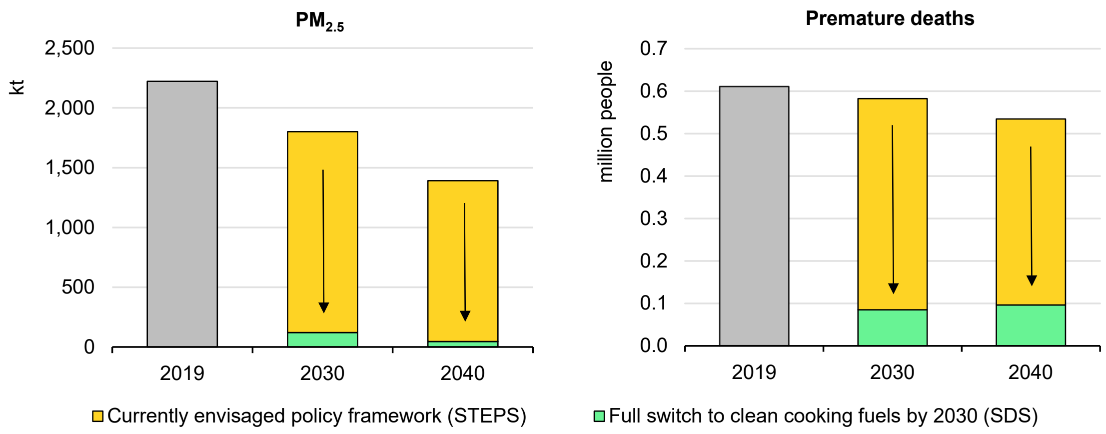
Successfully addressing $PM_{2.5}$ indoor air pollution in India will depend upon anticipated progress providing residential access to modern energy sources. A key driver to reduce indoor air pollution will require reducing the number of people without access to clean cooking facilities in rural areas from around 600 million in 2019 by 40% until 2040, along with switching nearly all urban households from solid biomass to liquefied petroleum gas (LPG) or piped natural gas (PNG) and, in some instances, electricity by 2040. These improvements could cut $PM_{2.5}$ emissions from the residential sector by 40% in 2040 in the STEPS. This achievement, combined with a reliable electricity supply, could also enable a phase-out of kerosene use for lighting, significantly reducing household fuel combustion and associated SO_2 emissions.

Residential CO_2 emissions are also expected to grow by nearly 50% between 2019 and 2040, driven by a range of developments. Stricter and more widely enforced building codes could ensure that new buildings are increasingly energy efficient and contribute to CO_2 reductions. Minimum energy performance standards for appliances help curb increase in electricity demand, particularly for air conditioners, for which ownership grows particularly rapidly. Energy demand driven by robust population growth combined with higher living standards is, however, expected to outweigh progress in building technologies. The drop in use of traditional biomass and an increasing level of appliance ownership are both expected to significantly contribute to increased residential electricity consumption to 2040. Despite the planned electricity supply decarbonisation, CO_2 emissions stemming from increased residential electricity demand remain more than three times higher than direct emissions from the residential sector in 2040.

Policy Integration Focus: Clean cooking air pollution and climate co-benefits

Enhancing the adoption of modern, clean energy sources can reduce air pollution and deliver major health benefits, but also significantly reduce GHG emissions. In 2019, India counted around 0.6 million premature deaths related to household air pollution. In the STEPS, premature deaths could remain above 0.5 million annually in 2040; however, achieving a full transition to clean cooking solutions by 2030 reduces this to fewer than 0.1 million deaths in that year (Figure 1.10).

Figure 1.10 Residential air pollution and population health, 2019-2040



Source: IIASA and IEA analysis.

Reducing the use of traditional biomass in residential buildings can significantly reduce air pollutants, but only fully switching to modern, clean cooking technologies by 2030 can nearly fully abate indoor $PM_{2.5}$ emissions by 2040, while reducing emissions from NO_X and SO_2 by 65-75% in the same timeframe. To achieve this, additional policy efforts are required. A transition to clean cooking fuel could further help mitigating climate change. Although switching from traditional biomass to clean, but fossil fuels, such as LPG and PNG, avoids a substantial amount of methane and nitrous oxide, their combustion generates CO_2, potentially leading to a slight increase in GHG emissions. However, considering climate impacts of black carbon emissions would largely outpace the increase in GHGs, clean cooking is a priority instrument to reduce global warming.

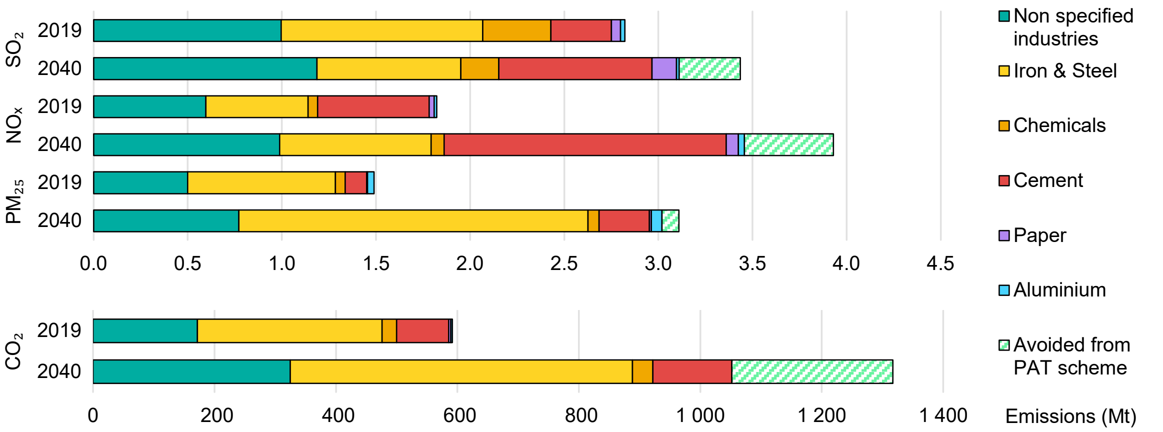
Industry is the key driver for emissions, but energy efficiency improvements could help

In 2019, India's industrial sector accounted for one-quarter of India's CO_2 emissions (590 Mt CO_2) and contributed one-fifth of total NO_X emissions and one-third of total SO_2 and $PM_{2.5}$ pollution. Large industry, namely iron and steel, chemicals and cement production, strongly rely on fossil fuels as an energy source and thus, with two-thirds of air pollutants and CO_2, account for the majority of industrial emissions. These three sectors see a tremendous growth in the next decades. Increasing their output by around 2.5 times between 2019 and 2040 results in doubling their industrial fossil fuel consumption over the same period in the STEPS.

Policy Integration Focus: Industrial energy efficiency air pollution and climate co-benefits

Since 2012, India's flagship programme for energy efficiency, the Performance and Trade Achievement (PAT) scheme, successfully enabled energy consumption savings in large industrial users. It remains a key policy to further reduce heavy industry's environmental footprint in the future. If continued and expanded, the PAT scheme could avoid 265 Mt CO_2, one-fifth of total potential industrial CO_2 emissions and more than 14% of SO_2 and NO_X pollution from large industry by 2040.

Figure 1.11 Industrial air pollution and CO_2 emissions by branch in the Stated Policies Scenario, 2019 and 2040



Source: IIASA and IEA analysis.

While efforts to enhance energy efficiency address combustion-related emissions, heavy industry generates a substantial amount of NO_X and SO_2 and more than 75% of $PM_{2.5}$ emissions during production processes. Therefore, CO_2 emissions from the industrial sector increase by nearly 80% and NO_X and $PM_{2.5}$ pollution almost double until 2040 in the STEPS (Figure 1.11). To strongly reduce the environmental footprint of India's industrial sector requires other measures in addition to the PAT scheme, for example, polices that target material efficiency in the iron and steel, cement and chemical industries as well as further develop and strengthen implementation of energy efficiency policies for small and medium enterprises.

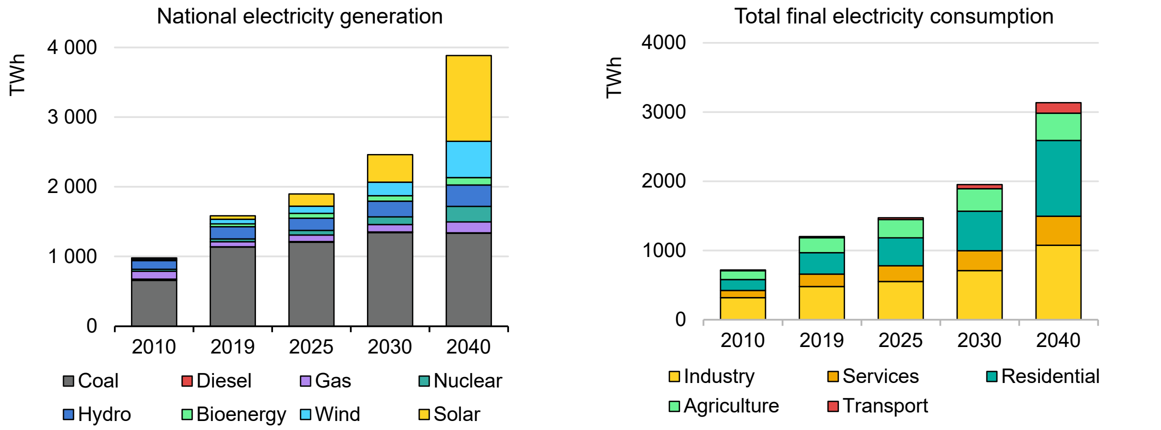
Chapter 2. Captive power plants

This chapter examines the environmental footprint of a specific segment in India's electricity sector: captive power plants, which in 2019 included almost exclusively fossil-fired plants installed by manufacturing and service companies in response to reliability and cost concerns from grid electricity supply to meet their own demand. While official data estimated the share of captive generation in India's national electricity supply to already be nearly 14% in 2019, this is likely a conservative estimate, as there is no clear data for the size and composition of this segment. Given its scale and heavily fossil-intensive generation mix, the captive segment needs to follow policy actions set out for the entire power sector on decarbonisation and air pollution control. Otherwise, captive power plants could continue to be an important source of CO_2 and air pollution emissions. The present analysis places the captive segment in the context of India's overall power sector transition strategy and presents available information regarding its status and environmental regulation. The chapter then examines how compliance with air pollution standards and enhanced renewables deployment within the captive segment could impact future emission levels.

India's captive segment within the national power sector

India's electricity generation has traditionally strongly relied on fossil fuels. In 2010, coal fuelled two-thirds and natural gas an additional 12% of the total electricity generated nationally (975 TWh). Strong economic growth drove electricity generation up by more than 60% to 1580 TWh in 2019, with coal-fired power plants providing 72% of total electricity generation (34Figure 2.1). While higher electricity consumption is linked to national economic development and industrial growth, the fossil fuel-intensive generation mix has significant environmental externalities. India's power sector emitted 1.1 Gt CO_2 in 2019 and was responsible for half of India's national SO_2 emissions. Since 2015, the GoI initiated important reforms to foster a clean power sector transition, promoting deployment of renewable energy sources and reducing the environmental footprint of existing thermal power plants.

Figure 2.1 India's total electricity generation and final consumption in the Stated Policies Scenario, 2010-2040



Captive power–industry's response to ensure affordable and reliable electricity supply.

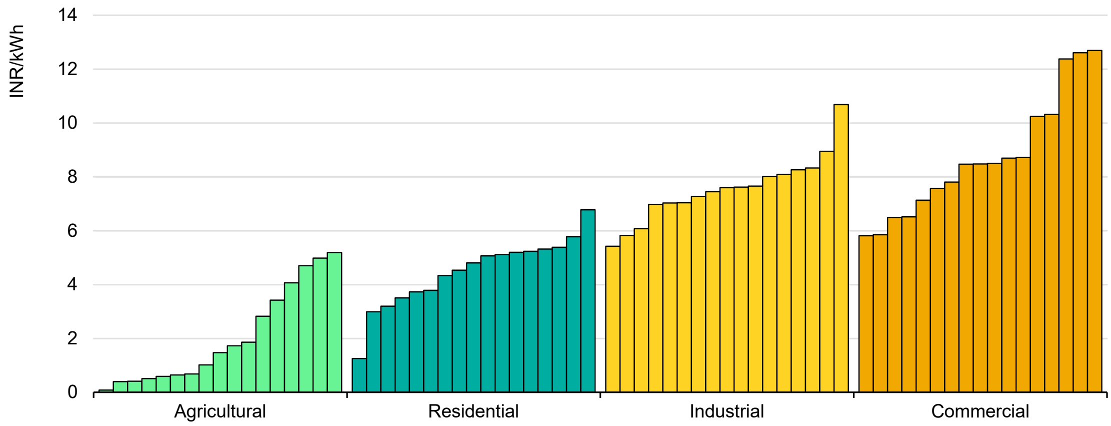
Secure, reliable and affordable electricity supply is crucial for efficient and competitive manufacturing and service sectors. When the grid electricity supply is not sufficiently reliable, industrial or commercial users may install so-called captive power plants (CPPs) to meet their electricity needs. Industry was India's largest electricity-consuming sector in 2019 at about 40% of electricity demand, followed by residential buildings (26%) and services (15%). Between 2010 and 2019, electricity demand from industry and commercial services increased by 55% and would more than double until 2040 in the Stated Policies Scenario (STEPS), equivalent to nearly 1500 TWh.

Captive power capacity growth in India was originally driven by the need for alternative power arrangements to provide better supply quality. In the past, industrial and commercial users relied on CPPs to meet about one-third of their electricity demand. CPPs also give industry the possibility to use the benefits of cogenerating electricity and steam for production processes.

More recently, cost savings have been an important factor. Costs of electricity supply are redistributed across sectors through the Electricity Act (2003) in line with various socio-economic development objectives, and tariffs are subsidised for the agricultural sector and low income, domestic consumers. This subsidy is partly recovered through higher tariffs for industrial and commercial consumers. Consequently, Indian industrial electricity prices are higher than in most emerging economies. In 2018, these amounted to USD 110 /MWh, compared to

USD 90 /MWh in the People's Republic of China or USD 75 /MWh in Indonesia. As per Section 42 of the Electricity Act (2003), electricity consumption from CPPs are exempt from cross-subsidy surcharges, it therefore often compares favourably with grid electricity procurement and offers an option to optimise energy costs. Industry demand has already left the grid in many cases and opted instead for self-generation. Since 2018, when electricity costs were higher than INR 6 /kWh, industrial consumers have tended to move towards captive power use. Recent IEA analysis found that distribution company (DISCOM) electricity prices exceed INR 6 /kWh in most states.

Figure 2.2 End-user prices by consumers in selected states, 2018



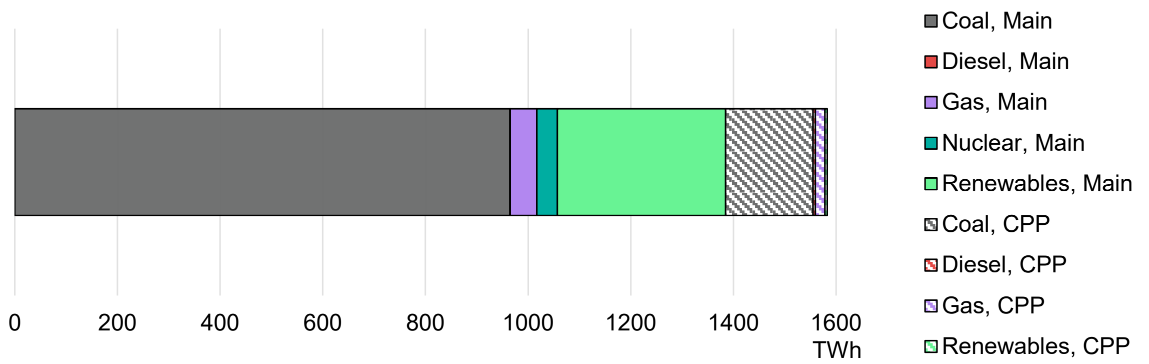
Source: IEA analysis based on PFC (2020).

While captive capacity serves primarily to meet specific industrial energy demands, since 1995 the Ministry of Power (MoP) has sought to further integrate CPPs within the power system. The Electricity Act (2003) gives CPPs open transmission access, allowing these plants contribute to the overall energy supply by selling their surplus power to the grid. To qualify as a CPP, a user must own at least 26% equity share capital in the plant and consume more than half of its average annual electricity generated. Further, the national Electricity Rules 2005 set out strategic steps for securing private investment in the power sector, mainly through captive power generation. According to the India's Central Electricity Authority (CEA), however, in 2014/15 only about 9% of the captive electricity generated was exported to utilities.

Captive power in India's electricity supply today

CPPs are crucial to India's electricity supply since the beginning of the country's industrialisation. The exponential growth of India's industrial sector over the past two decades was accompanied by substantial growth in captive power capacity installations. According the CEA, total installed captive capacity that exceeded 1 MW was only around 15 GW at the start of the 2000's, and grew to 78 GW by 2019.[1] The Indian Captive Power Producers Association and other survey-based studies estimate that total CPP capacity may have exceeded 80 GW in 2017. The highest shares of captive capacity and largest CPPs – all coal-fired[2] – are found in metal and mineral sub-sectors, such as aluminium, copper, iron and steel, as well as cement. Other industries, such as petrochemicals or fertilisers, have also seen significant deployment of CPPs.

Figure 2.3 India's electricity output by main and captive generators, 2019



Source: IEA analysis based on data from WEO (2020) and CEA (2020).

As CPPs primarily hedge against unreliable grid supply, their capacity utilisation has always been relatively low. The average plant load factor of the entire captive segment was approximately 31% in 2019, compared to a national average for non-captive of 50%, but differed significantly across fuels. Nonetheless, CPPs are important for overall electricity supply security. In 2019, India's captive plants generated 215 TWh, nearly 14% of total generation in that year; this is much higher than the global average of 7.2% and substantially higher than in advanced

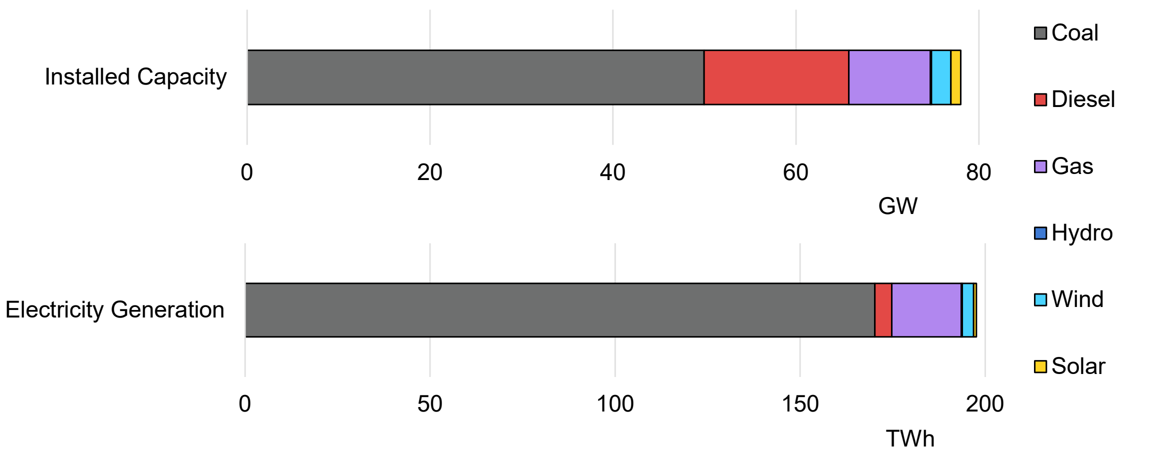
[1] It is important to note that the true extent of the captive segment is unknown and growth in capacity does not only stem from actual, new plant installations, but also from new information. The MoP recently updated their estimate from 58 GW to 78 GW in 2019.

[2] Examples are Vedanata's 1.1 GW CPP in Jharsuguda, NALCO's 1.2 GW CPP or Jindal Steel and Power Limited's 0.81 GW CPP, both located in Angul.

economies, where CPPs generate on average 4-5% of total electricity. Captive plants provided one-third of industrial and commercial electricity demand in 2019.

The captive power segment's capacity and generation mix is more fossil-fuel intensive than the national average (Figure 2.3). According to the CEA, coal-fired CPPs comprised 50 GW, 64% of captive capacity and 87% of captive electricity generation in 2019, owing to their relatively high load factor of 43%. Gas-based CPPs added another 9 GW (11%), providing 9% of captive power generation.

Figure 2.4 Installed captive power capacity and its electricity generation by fuel, 2019



Source: IEA analysis based on data CEA (2020).

The CEA estimated in 2019 that diesel generators accounted for 16 GW or one fifth of the captive capacity. Their extremely low average utilisation of 3% underscores their function to supply peak and back-up power. They provided about 5 TWh of electricity in 2019, accounting for almost all national oil based electricity generation (Figure 2.4). The true extent of diesel generator use across the country is unclear, however, as official data only include units of more than 1 MW. Studies based on manufacturer data indicate that total capacity could be around 72 GW and possibly even as high as 90 GW, with annual sales of around 5-8 GW. Assuming a low load factor of 3%, this fleet of small diesel generators could be generating almost 30 TWh of electricity annually. Most diesel-based generation in India is captive power for small businesses and households. Made up of small units and owing to high fuel costs, they are relatively expensive to operate and thus, usually used only sparingly to counterbalance power outages. Nevertheless, they are a significant source of local noise and air pollution.

Potential trends in India's captive power segment

Surveys in 2019 found that over 16 GW of additional captive power capacity was at various development stages across all fuel segments, though prospects differ across fuels. For thermal CPPs, the lack of adequate fuel supply has recently emerged as a key concern, as utilities and independent power producers receive priority coal allocation. Such regulations might reduce incentives to further invest in new thermal CPPs in the future. In addition, as gas networks expand within cities, use of gas-based generation could become viable for larger users in urban areas. Nonetheless, large coal-based captive plants for energy-intensive industry are likely to continue to dominate the captive segment in the medium term. While CPPs based on renewable energy sources were still limited in 2019 (3.3 GW or 4% of captive capacity, generating about 4 TWh), recently large commercial and industrial consumers have made considerable investments in solar-powered captive plants,[3] underpinning its future potential. However, in late 2020 the MoP issued a regulation that excludes rooftop solar systems over 10 kW from net metering. This might deter businesses from further investments, as net metering has been an important selling point for the commercial segment. Because solar- and wind-powered plants are variable and unable to provide back-up generation, their potential to serve as captive plants is too limited for some industrial and commercial consumers. While rooftop solar was seen as gradually replacing diesel-fired generation for smaller commercial users and residential buildings, implementation will require appropriate incentives, including through a favourable and stable regulatory environment. In time, improved reliability of grid electricity would be most conducive to a sustainable energy transition. This could encourage commercial and industrial users to rely on the grid instead of captive plants, with grid electricity remaining subject to clearer policy plans for decarbonisation and air pollution regulations.

In the 2018 National Electricity Policy, the CEA included projections for electricity generation from CPPs reaching almost 340 TWh by 2026, of which 255 TWh would be consumed by industry and 25% transferred to the grid supply. However, the report does not consider this "a likely scenario", stating that high industrial and commercial electricity tariffs make it cheaper to set up CPPs, and that there has, on the contrary, "been increasing interest to set up or take equity in captive power plants, signifying a shift away from grid supply". If captive power plants continue

[3] For example, Aditya Aluminium invested INR 1.51 billion to install a 24 MW captive solar plant in Odisha, commissioned end of 2019 and Indian airports started to explore their potential for solar power plants.

to supply about one-third of the industrial and commercial electricity demand, the segment's generation would increase to 490 TWh by 2040.

India's power sector transition – ambitious and needed.

Power sector decarbonisation

Ahead of Paris Agreement preparations in 2015, the GoI decided to foster power system decarbonisation by setting a target of 175 GW of newly installed renewable energy capacity by 2022, including 100 GW from solar, 60 GW from wind, 10 GW from bio-power and 5 GW from small hydropower.[4] At the 2019 UN Climate Action Summit, India's Prime Minister enhanced this target to 450 GW installed renewable capacity by 2030.

By achieving these targets, India's electricity generation fleet will shift towards more low-carbon energy sources in the coming years. Despite increasing its generation by 200 TWh and thus remaining the largest energy source for electricity generation, coal-based electricity will reduce its share in total generation to one-third by 2040. The surge in electricity demand will mainly be covered by renewables, which in 2040 would provide more than half of India's electricity generation. Solar is likely to be significant in decarbonising India's electricity generation, with a generation output of over 1 230 TWh (32% of the total) by 2040.

Environmental regulation of India's thermal power plants

The GoI has been working to implement stricter environmental standards for thermal power plants since 2015, but this has been repeatedly delayed. These regulations are important considering thermal power accounted for 205 GW or over half of total installed power capacity and nearly three-quarters of generation in 2019. India's coal-fired power plants are among the most inefficient in the world; the sector's performance is significantly below global benchmarks, contributing substantially to local air pollution. In 2019, India's power sector was responsible for half of total SO_2 emissions, about 25% of NO_X and 10% of $PM_{2.5}$. In addition, it accounts for 80% of industrial mercury emissions.

Until 2015, power plants in India were required to meet PM emission standards that were much less stringent than standards in China, the United States or Europe, and there were no national regulations for SO_2 or NO_X emissions from

[4] Hydropower plants with a capacity of >25 MWGW do not fall in the category of renewable energy sources in India.

thermal power plants. Existing standards only related to chimney height to ensure that the flue gas was dispersed to limit incremental ambient concentration. However, increasing levels of pollution from other sources in combination with a strong growth in thermal power generation has made this single control method inadequate. In December 2015, the Ministry of Environment, Forest and Climate Change (MoEFCC) proposed stricter environmental standards for coal-based thermal power plants through an amendment of the Environment (Protection) Act Rules (1986). In the original revision, generally referred to as "emission standards notification, 2015", all plants were required to meet the new environmental standards by December 2017. However, most utilities were unable to implement measures to meet the standards within two years without impacting power supply reliability. The MoP formed a committee to develop an action plan to implement the norms, including members from the CEA, Ministry of Coal, MoEFCC and CPCB. In 2017, the CPCB issued directives for all thermal power plants to meet a final deadline of 2022 for all air pollutants. However, in March 2021, the MoEFCC extended the compliance deadlines again from 2022 to 2024 based on a request from the MoP related to delays from the Covid-19 pandemic.[5]

Table 2.1 Air pollution emission standards for thermal power plants

Air pollutant	Installation date of thermal power plant		
	Before 2004	2004-2016	2017 onwards
PM	100 mg/Nm^3	50 mg/Nm^3	30 mg/Nm^3
SO_2	600 mg/Nm^3	200 mg/Nm^3	100 mg/Nm^3
NO_X	600 mg/Nm^3	300 mg/Nm^3	100 mg/Nm^3

Plant-wise deadlines to comply with emission standards were issued by the CPCB, ranging between end of 2018 (immediately) and 2022, but are subject to a potential extension up to 2024.

Note: The MoEFCC relaxed NO_X norms from 300 mg/Nm^3 to 450 mg/Nm^3 in October 2020.

Specific emission standards vary by pollutant and the plant's commissioning date and specify limits for four pollutants and water consumption. Emission standards for PM, SO_2 and NO_X are presented in Table 2.1. Comparatively speaking, the emission norms for thermal plants installed from 2017 onwards are similar to those in place in China and the United States, while EU standards remain stricter.

[5] Retiring thermal power plants can obtain extensions up to 2025.

In 2019, nearly half of India's thermal plants (excluding the captive fleet), complied with emission norms for particulate matter and an additional 7% were in the process of complying. The MoEFCC relaxed NO_X emissions standards from 300 mg/Nm^3 to 450 mg/Nm^3 in October 2020. While implementation progress data for most plants was unavailable in 2019, the dilution of NO_X standards allow about 75% of thermal capacity to comply. However, only 6% of India's thermal power plants complied with their SO_2 norms, and only about 26% had contracted the installation of flue-gas desulphurisation (FGD) technologies, while around two-thirds are still in the first stages of feasibility studies and tendering procedures or have not yet taken action. As it generally takes more than two years to complete FGD installation, it is highly unlikely that these can meet the new SO_2 emission standards until 2022. However, installing a SO_2 control device is crucial, as such systems only work efficiently when PM and NO_X standards are met, acting as a cross-check mechanism. It should be noted that a few power stations, including the National Thermal Power Corporation are readying to comply with the emission standards.

Environmental regulation of India's thermal captive power plants

As of the end 2017, there was no clarity as to whether the revised emission standards would also apply to captive thermal plants. In April 2018, the CPCB issued state-specific orders for thermal CPPs, requesting them to comply with the 2015 emission standards for PM and SO_2 by 30 June 2020 at the latest, setting a tighter time plan for CPPs than for thermal utilities.

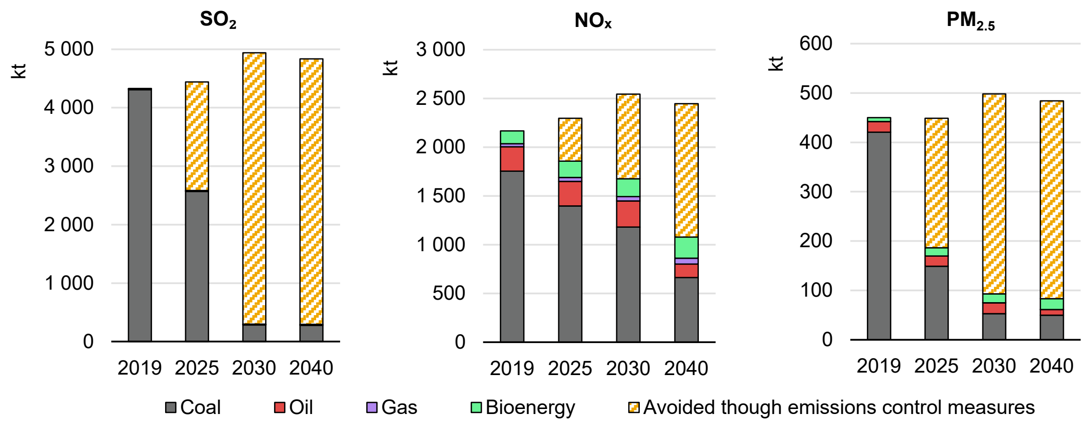
For NO_X pollutants, the same 2022 deadline given to the thermal utilities applies. Plants using fluidised-bed combustion technologies were required to meet the standards for PM and SO_2 by the end of 2018, while plants that had yet to install FGD equipment had until 30 June 2020 to comply with SO_2 standards. Some companies already started tenders for emission control equipment such as FGD installations (e.g., Vedanta, 2020), however, over 75% had not yet started this process in 2019. In practice, CPPs did not move towards complying with the standards. Industry bodies requested an extension of these deadlines in July 2020, requesting the government to acknowledge that commissioning an FDG installation takes more than two years after clarifying all regulatory and financial issues. Given the limited tendering processes for equipment to date, it appears unlikely that most captive thermal power plants will meet the air pollution standards by 2022.

Impacts to the air quality and climate of India's power sector

Air pollution from India's power sector

In 2019, the power sector accounted for nearly 30% of NO_X, 13% of $PM_{2.5}$ and more than 60% of SO_2 from all combustion-related emissions. Even though domestic coal has a relatively low sulphur content, it also has low calorific values and a high ash content. Coal-fired plants generated all power-related SO_2 emissions and nearly 95% of power-related $PM_{2.5}$ emissions. Coal-fired plants emitted 80% of NO_X emissions, with diesel generators accounting for at least 12% (Figure 2.5).

Figure 2.5 Air pollutant emissions from the power sector in the Stated Policies Scenario, 2019-2040



Source: IIASA and IEA analysis.

Installation of adequate emission control technologies in thermal power plants could significantly reduce air pollution. Doing so would enable a reduction of 95% combustion-related SO_2, nearly 80% of $PM_{2.5}$ and 25% of NO_X emissions by 2030 compared to 2019 levels. If today's thermal power plants do not implement emissions-reducing technologies to meet air pollution standards, air pollution would significantly worsen given the increased electricity demand across all sectors. By 2030, SO_2 emissions could reach nearly 5 Mt, more than 17 times higher than with emission control equipment. Further, $PM_{2.5}$ pollution could increase 15% from 2019 levels, 5 times as much as within a setting where emissions regulations are fully implemented. Finally, NO_X emissions would also increase 17% until 2030. Air pollutant emissions would likely begin decreasing slightly after 2030, even in the absence of pollution control measures, as electricity generation from thermal plants will gradually be replaced by renewable sources.

Carbon dioxide emissions from India's power sector

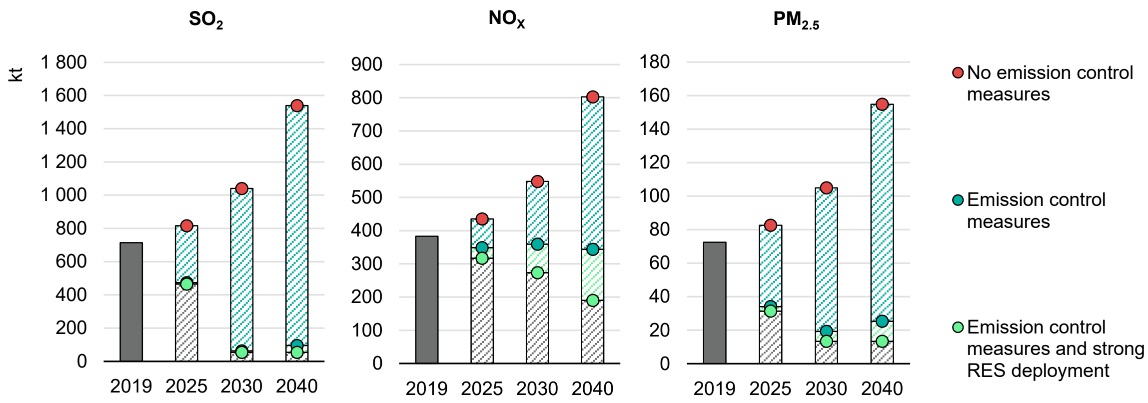
In 2019, India's power sector emitted 1.15 Gt CO_2, about 90 Mt CO_2 more than in 2015, with coal's share at 95%. Owing to the Covid-19 crisis, coal-fired power plant CO_2 emissions fell by 5% in 2020, adjusting generation for lower electricity demand from industries and freight transport. However, total power sector-related emissions are projected to surpass 2019-levels by 2025. In the STEPS, these emissions increase until mid-2030, peaking at around 1.32 Gt CO_2, and only then gradually decrease when renewable energy sources such as solar PV, wind and hydro power plants start to replace fossil-fuelled plants.

Air pollution and carbon emissions from the captive power segment

While generating almost 14% of India's total electricity in 2019, captive power plants accounted for 16-18% of all power-related CO_2 and air pollution emissions. The captive power segment has a greater share of coal and diesel in its generation mix than the national average and lacks an adequate implementation strategy for air pollution control measures. As 87% of the captive generation mix is coal, this fuel accounts for nearly all SO_2, 90% of $PM_{2.5}$ and CO_2 and 75% of NO_X emissions.

Captive power plants are projected to continue to supply electricity to the industrial and commercial sector. Captive electricity generated could exceed 320 TWh in 2030 and could reach as much as 490 TWh by 2040. The environmental footprint of the growing captive segment will be critically determined by environmental regulation of fossil-fuelled plants and the potential decarbonisation of its generation mix.

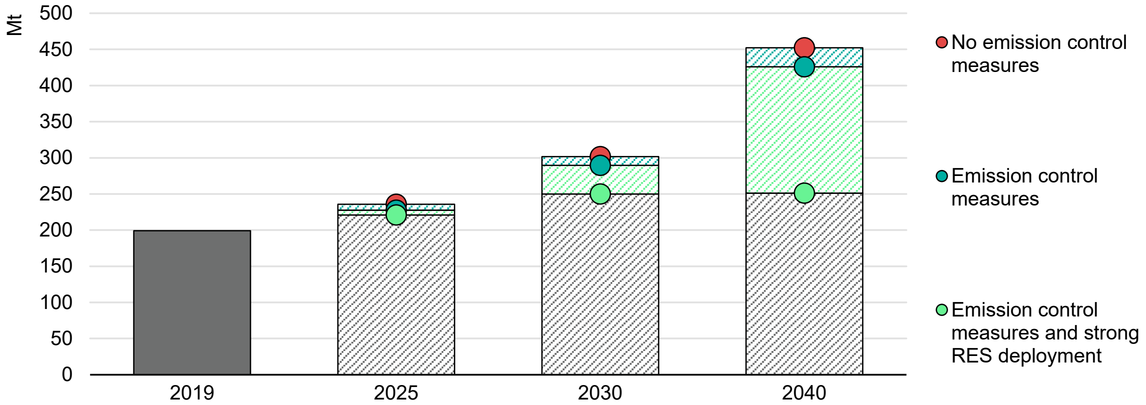
Figure 2.6 Air pollutant emissions from CPPs in 2019 and potential outlook, 2025-2040



Implementing emission control measures will be vital to limit air pollutant emissions (Figure 2.6). Even if captive electricity generation continues to rely on coal for over 85% of fuel supply as in 2019, full implementation of emission control measures by 2030 would reduce SO_2 emissions by nearly 90%, $PM_{2.5}$ by 65% and NO_X by 10% in 2040, despite a strong growth in total generation. Additionally shifting the fuel mix away from coal and towards rooftop solar power within captive generation would have an even greater impact. If solar accounted for one-third of CPPs in 2040, like its share in the national mix if current targets are met, this could reduce $PM_{2.5}$ and NO_X emissions by another half. However, if captive thermal plants fail to implement air pollution control technologies, emissions across all air pollutants would more than double and SO_2 emissions could reach a level of more than 1.5 Mt in 2040, 16 times higher than if measures are implemented.

The generation mix of captive plants will largely impact their CO_2 emissions. Air pollution control implementation would reduce CO_2 emissions by 6% in 2040, compared to a situation where plants do not comply with the standards. Even with strong air pollution regulations, annual emissions from CPPs would still more than double to 420 Mt CO_2 in 2040. However, a fuel switch towards renewable energy sources through an ambitious deployment of solar PV could curb emissions to about 250 Mt CO_2 in 2040, 45% lower than if no actions are taken to clean the captive power segment (Figure 2.7).

Figure 2.7 CO_2 emissions from CPPs in 2019 and potential outlook, 2025-2040



It is important to note that emissions estimates for India's captive segment are rather uncertain and likely conservative for a few reasons. First, available data is patchy and only captures units with a capacity above 1 MW. Without knowing the extent of units with much smaller capacity, in particular most of the diesel generation fleet, it is not possible to accurately estimate the extent of fuel consumption and air pollution stemming from this segment. Second, most captive thermal plants are smaller than utility plants, while having a similar age structure. Therefore, the captive thermal fleet should be less efficient on average, meaning their fuel consumption and pollution per kWh generated is likely higher than estimates based on those of larger units. Given the uncertainties regarding the true extent of India's captive fleet, in particular diesel generators with a capacity of < 1 MW, it is important to improve data quality. This would better enable a policy framework tailored to the particularities of the captive segment and allow for adequate monitoring, regulation and for incentives to shift to a cleaner generation mix.

Chapter 3. Road transport electrification

Road transport electrification must happen alongside reducing the environmental impacts of the power sector

One effect of India's economic boom has been a nearly sevenfold increase in passenger car ownership over the last two decades. As most road traffic occurs in densely populated areas, this led to significant increases in urban air pollution levels. Further, vehicle tail pipe emissions occur close to the ground, lowering the pollution's dispersion, making urban emissions particularly dangerous for pedestrians. Overall, India suffered about 74 000 premature deaths related to transport emissions in 2015.

Recognising this problem, the GoI has adopted tighter nationwide emissions standards for vehicles, Bharat Stage (BS) VI, nearly equivalent to Euro 6 norms, and stated an ambition to reach a share of 30% electric vehicle (EV) sales across all road vehicle types by 2030. EVs have zero tailpipe emissions and can therefore significantly reduce local air pollutants and carbon emissions that directly stem from the transport sector. At the same time, increased use of EVs raises electricity demand. India's current electricity mix depends largely on fossil fuels, while delayed implementation of air pollutant control measures means than thermal power plants remain deeply emission intensive (see Chapter 2). Consequently, additional electricity consumption from EVs could increase CO_2 emissions and lead to a strong growth in SO_2 pollution, if not aligned with reducing the CO_2 intensity of electricity and ensure the coal-fired plants' compliance with tighter emissions.

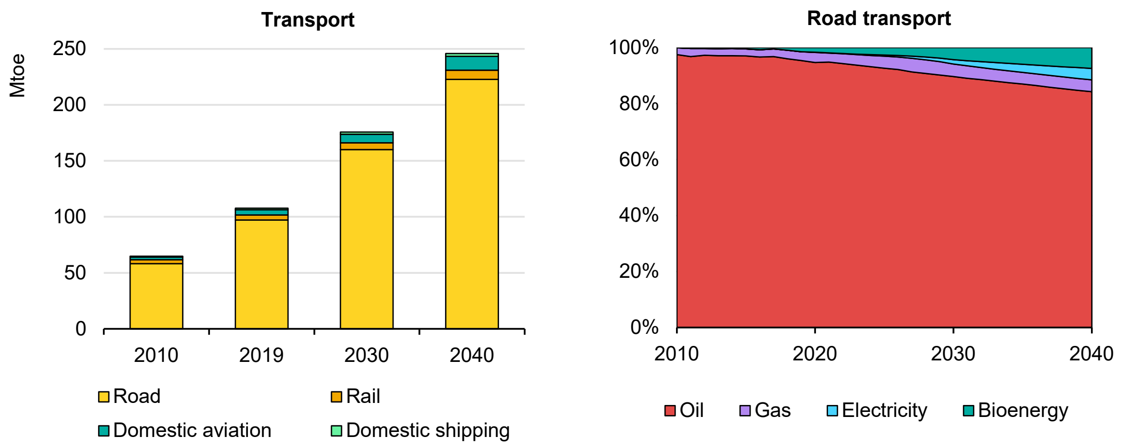
In addition, road transport electrification will generate benefits other than lower air pollution and GHG emissions reductions, including enhancing economic development and energy security. Domestically produced electric vehicles could provide India an opportunity to develop a world-class manufacturing sector and offer a new avenue for employment in an economy facing structural changes. Large-scale adoption of EVs also allows the country to reduce its import dependence on oil, today largely consumed in the transportation sector. For increased road transport electrification to significantly reduce CO_2 emissions and SO_2 pollutants, it must happen alongside an ambitious power sector transformation.

Transport sector profile and environmental policy framework

Energy consumption of the transport sector

India's transport sector accounted for 17% of total final energy consumption (TFC) in 2019, a relatively low share compared to other IEA member countries where transport makes up 16-54% of TFC. However, India's transport sector demand is growing rapidly, more than tripling over the past two decades to almost 110 Mtoe in 2019, driven by economic growth and increased private mobility. In the IEA Stated Policies Scenario (STEPS), energy consumption in the transport sector continues to grow at an annual average of 5% to reach nearly 180 Mtoe in 2030. Road transport currently makes up about 90% of the transport TFC and will continue doing so in the STEPS, despite growth in rail and aviation transport (Figure 3.1).

Figure 3.1 Final energy use of transport by subsector and road transport by fuel in the Stated Policies Scenario, 2010-2040



Road transport electrification framework

To realise the various benefits of road transport electrification, the GoI announced in 2018 the ambition to reach 30% EV sales by 2030 across all road transport modes, including two/ three-wheelers. This builds upon the previous target of 6-7 million EV sales until 2020, established in the National Electric Mobility Mission Plan (NEMMP) 2020. Launched in 2012 by the Department of Heavy Industry, the NEMMP 2020 is the roadmap of the National Electric Mobility Mission (NEMM) and provides the vision and central strategy to boost both manufacturing and adoption of EVs in India. Additionally, Niti Aayog proposed in 2019 that two-wheelers below a capacity of 150 cc sold from April 2025 onwards should be electric only.

India's approach to promote transport electrification has evolved in recent years. The present national policy framework is a mix of incentive-based measures, accompanied by regulatory reforms, public-private partnerships that encourage EV adoption and expansion of charging infrastructure as well as support schemes for EVs and battery manufacturing.

India's flagship Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme was, launched in April 2015 under the NEMM, providing incentives to stimulate market development. It encouraged electric and hybrid vehicle purchase by providing extensive financial support to reduce the relatively higher upfront costs of EVs. Its first phase ran for four years until 2019, and the second phase (FAME II) is set to run until April 2022 with a budget of about INR 100 billion (USD 1.4 billion). Vehicle coverage and incentive levels were amended in FAME II, with the largest share of incentives available for electric buses (41%), followed by three-wheelers (29%) and two-wheelers (23%). However, purchase subsidies are available only for advanced battery chemistry vehicles (excluding lead-acid), which excludes a wide range of electric two-wheelers. While FAME II covers electric four-wheelers, most available models exceed the maximum eligible sticker price of INR 1.5 million (USD 21 300). To compensate, an income tax exemption of INR 150 000 (USD 2 130) on loans for EV purchases was announced in the 2019-2020 federal budget. Moreover, the GoI reduced the goods and service tax for electric vehicles from 12% to 5%.

India's largest energy savings company, Energy Efficiency Services Limited (EESL), has been leading a bulk procurement programme for EVs within the national government vehicle fleet since 2017, aiming to transform the vehicle fleet across the country. Initially, it launched a tender for 10 000 EVs, but the first 1 500 cars took nearly two years to roll out with technical issues raised regarding vehicle range and quality. Learning from the first tender, in 2020 EESL floated a new tender for an additional 1 000 EVs with more advanced technical specifications to consider for the rapid changes in technology.

In India, key aspects of transport policymaking and implementation are within the jurisdiction of the states, which will largely execute deployment of national EV targets. Several states, among them Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Tamil Nadu and, most recently, the NCT Delhi have developed state-level roadmaps and policy guides to promote policy consistency Often, specific policy approaches vary by local context and state-implemented policies create unique financial incentives, such as duty waivers, exemptions from permit fees, streamlined registration processes and supporting infrastructure to encourage EV uptake and charging station deployment.

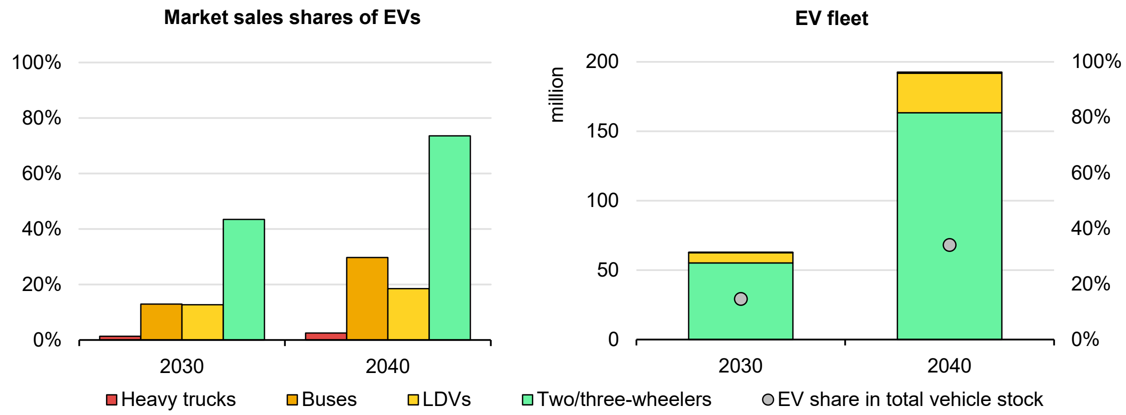
Additional regulatory policies that address air pollution have the co-effect to improve cost competitiveness of EVs compared to conventional cars with internal combustion engines (ICEs). In 2016, the Ministry of Road Transport and Highways initiated a draft notification to significantly tighten emission standards for all primary on-road vehicle categories to Bharat Stage (BS) VI, leapfrogging the BS V standards previously laid out in the Auto Fuel Vision and Policy 2025. These new norms essentially align emission standards to the European Union regulation levels and became effective for all vehicles manufactured after March 2020. With this decision, the GoI BS VI reduces diesel and gasoline sulphur content permitted from 50 to10 ppm nationwide. Further, other fuel characteristics that affect the engine's thermal efficiency are now subject to tighter standards. In terms of GHG emissions, light duty vehicle (LDV) manufacturers must meet a car fleet average of 130 g CO_2/km in April 2017 and 113 g CO_2/km in April 2022. This is equivalent to a nominal 13% reduction over this period.

India also engages internationally to accelerate EV deployment. It participates in the Electric Vehicle Initiative (EVI) and its EV30@30 Campaign, which sets a collective aspirational goal for all EVI members to achieve a 30% market share for electric vehicles against total vehicles sales (excluding two-wheelers) by 2030.

Achievements in road transport electrification

The outlook for EV sales growth is linked to overall car market trends. Already in 2019, total passenger car sales volumes were depressed in many key economies, including India. In the wake of the Covid-19 crisis, India saw registered EV sales drop by about one-quarter on average in 2020 compared to 2019. Further, coverage of only advanced battery chemistries under FAME II, with incentives based on battery size, also negatively impacted sales of electric two-wheelers. Nonetheless, sales in this segment fell only about 6% in 2020 compared to 2019.

Figure 3.2 EV share of vehicle sales and fleet by vehicle type in the Stated Policies Scenario, 2030 and 2040

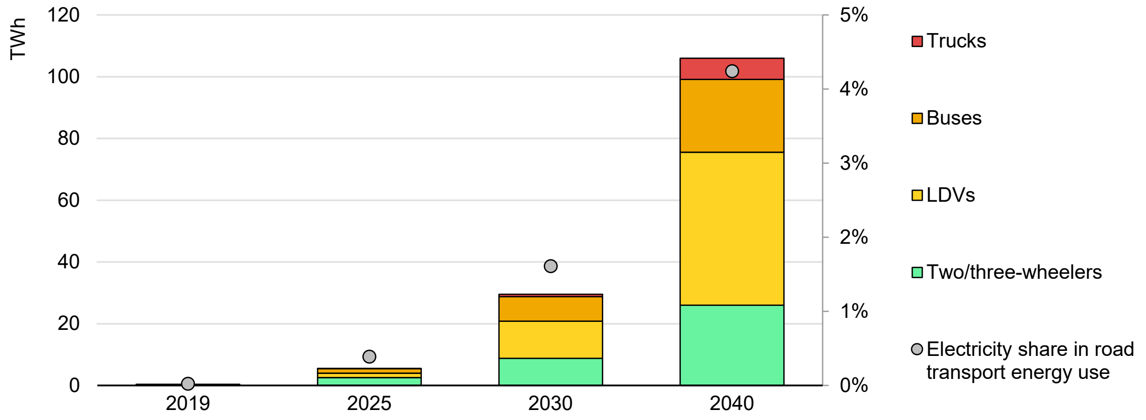


Note: LDV = Light Duty Vehicle, including passenger cars such as vans and SUVs and small commercial trucks.

The IEA estimates that EV market penetration was only around 3% of India's total vehicle sales in 2019, the largest majority of which were electric two/three-wheelers. Nonetheless, prospects for India's EV market remain strong. Despite high upfront costs, EVs are gradually becoming more competitive based on the total cost of ownership. To achieve the government's aspiration of an average 30% EV sale shares by 2030 will mainly be achieved through electrification of two/three-wheelers, with sales reaching a market share of more than 40% of this segment in 2030. The rate of bus and LDV electrification is likely to remain much lower, with less than 15% sales share in 2030 (Figure 3.2).

India's EV fleet contained about 14 000 cars and buses and nearly 1.8 million two/three-wheelers in 2019, and growth in uptake means EVs will progressively represent an ever-larger share of the overall vehicles stock in the future. In the STEPS, India's EV fleet will account for about 15% of the total vehicle stock in 2030 and by 2040 for more than one-third. This progress helps to shift a part of transport fuel demand from oil to electricity. India's EV fleet consumed 0.3 TWh electricity in 2019, accounting for just 0.02% of total road transport fuel consumption. In the STEPS this share reaches about 2% by 2030 with EVs demanding nearly 30 TWh. This corresponds to nearly 6% of global electricity demand from EVs. Two-thirds of the Indian EV fleet's electricity demand would arise from passenger cars and two/three-wheelers (Figure 3.3).

Figure 3.3 Electricity consumption from EVs by mode in the Stated Policies Scenario, 2025-2040

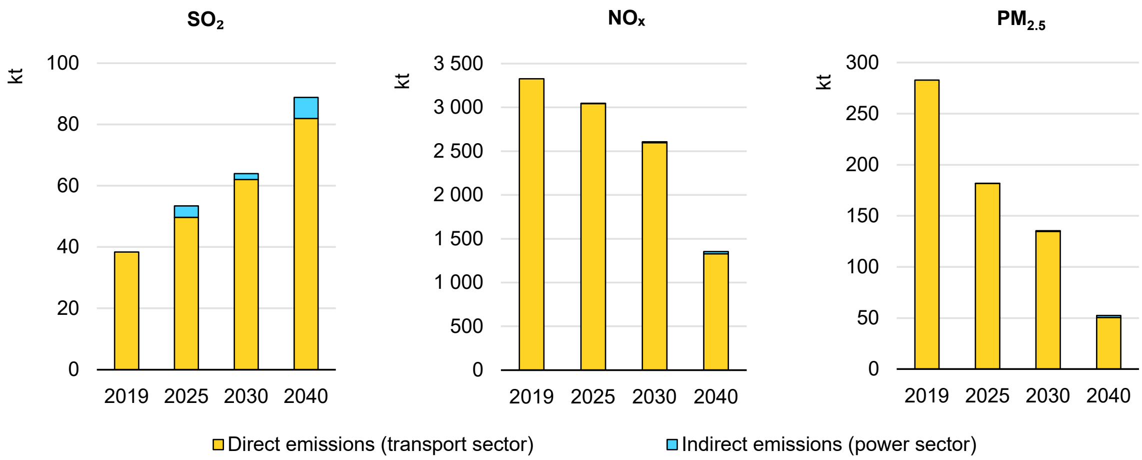


Impacts on air pollution

Road transport creates most transport related air pollutant emissions, namely NO_X and $PM_{2.5}$. In 2019, road transport directly emitted 3.3 Mt (45%) total NO_X emissions from fuel combustion activities. While its direct contributions towards pollution of SO_2 are, with 1%, marginal, road transport emitted 8% combustion related $PM_{2.5}$ emissions. Implementing existing policies, including stricter fuel and vehicle standards, could lead road transport related NO_X emissions to peak around 2025 and then fall by 55% by 2040, reaching 1.3 Mt NO_X. This would reduce road transport's share of combustion-related NO_X emissions to one-quarter by 2040.

In addition to these direct emissions, the growing EV fleet adds indirect emissions from the electricity generation required to fuel these vehicles. Road transport related electricity consumption contributes a negligible amount to total road transport NO_X and $PM_{2.5}$ emissions, which will not significantly change in the future. In contrast, additional indirect SO_2 emissions from EV electricity consumption require more attention as they are set to increase by a factor of 20 until 2040 in the STEPS. The planned rapid rollout of EVs in next decade will lead to a surge in road transport related electricity demand, while full desulphurization of the heavily coal-reliant power sector will be achieved only in the late-2020s under current regulations and enforcement pace. Consequently, indirect EV-related SO_2 emissions could jump from zero to 4 kt in the next years. Once coal-fired plants have fully implemented air pollution control technologies and met their revised emissions standards, 2015, SO_2 emissions nearly halve again by 2030, despite continuous EV deployment. Afterwards, they gradually increase through additional electricity demand from annually deployed EVs. India's EV fleet will account for 8% of total road transport related SO_2 emissions by 2040 as projected in the STEPS. Nonetheless, all road transport activities are likely to continue contributing less than 5% to national SO_2 emissions from combustion activities (Figure 3.4).

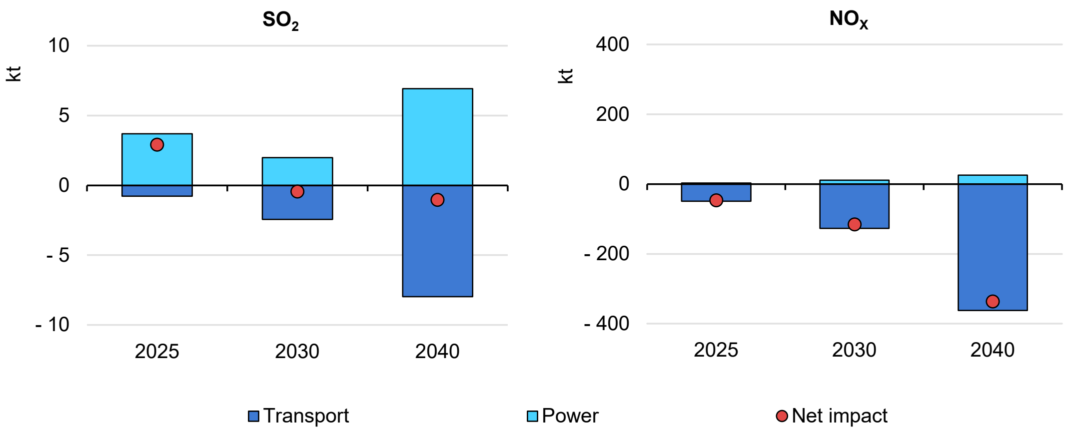
Figure 3.4 Road transport related air pollutant emissions in the Stated Policies Scenario, 2019-2040



Note: Presented emission levels do not consider road transport related non-exhaust emissions from brake and tyre wear, road abrasion or resuspension of road dust.
Source: IIASA and IEA analysis.

The net impact of India's transport electrification on air pollution will depend upon progress with implementing stricter emissions standards within both the transport and power sectors. Achieving a rapid acceptance of EVs within the next decade reduces the demand for ICEs, shifting use of transport fuels from oil to electricity. This allows for a comparison of avoided air pollution from displaced oil consumption and additional pollution through the EVs' increased electricity use. Switching from oil to electricity as a road transport fuel saves a substantial amount of NO_X pollution. In the period between 2030 and 2040, transport electrification could annually avoid about 12 times the emissions emitted due to the increase in electricity demand, saving 0.33 Mt NO_X in 2040. The net impact of transport electrification on $PM_{2.5}$ pollution shows a reduction but remains limited. However, before achieving a full desulphurization of the power sector, EV electricity consumption could add about 5 times more SO_2 than is avoided if not using an ICE vehicle. Once India's coal-fired fleet complies with SO_2 emissions standards, EV deployment could reduce impact on SO_2 emissions, despite continued growth in electricity consumption. By 2040, the EV fleet could emit 13% less SO_2 than an equivalent ICE fleet (Figure 3.5).

Figure 3.5 Avoided and indirect SO_2 and NO_X emissions through EVs in the Stated Policies Scenario, 2025-2040

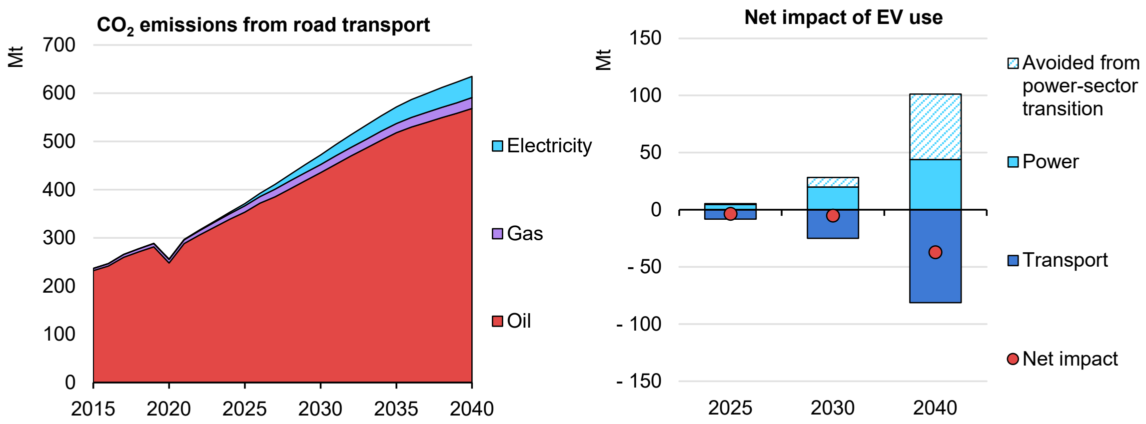


Deferring the implementation of the tightened emissions standards, 2015 for coal-fired power plants beyond 2030 has severe repercussions for the net-impact of road transport electrification. Doing so could result in the EV fleet's indirect SO_2 emissions reaching 0.12 Mt SO_2 in 2040, 18 times the amount expected in a scenario where the revised emissions standards for coal-fired power plants are fully implemented. While vehicle emissions standards and road transport electrification significantly reduce exhaust-related emissions, attention must be paid to non-exhaust emissions, such as from brake and tyre wear and resuspension of road dust, which are not necessarily mitigated by EV deployment.

Impacts on carbon dioxide emissions

India's transport sector directly emitted almost 320 Mt CO_2 in 2019, 14% of the country's carbon emissions; 90% stemmed from road transportation. Emissions from transportation are set to rise in the STEPS to more than 450 Mt CO_2 by 2030, increasing its share of total emissions from 12% to 15%. This trend is likely to continue until 2040, when road transport related emissions could reach nearly 600 Mt CO_2, resulting from the continuing substantial increase in transport activity.

Figure 3.6 Road transport related CO_2 emissions and the net impact of EV use in the Stated Policies Scenario, 2015-2040



In addition to direct emissions from fuel combustion in the transport sector, growing use of EVs leads to indirect emissions in the power sector. While these emissions amounted to less than 0.5 Mt CO_2 in 2019, their importance is expected to grow with the uptake of EVs. By 2030, CO_2 emitted by EV electricity consumption could reach 20 Mt CO_2, and afterwards more than double until 2040. This is because the rapid uptake of EVs to 2030 is not matched by simultaneous electricity supply decarbonisation at the same pace. By 2040, CO_2 emissions from electricity used in road transport could account for 7% of total road transport emissions (Figure 3.6).

Increased road transport electrification will result in some future transport fuel demand shifting from oil to electricity. Comparing displaced CO_2 emissions through reduced oil consumption with additional CO_2 emissions from increased electricity use shows the potential net impact of EV deployment. To lower well-to-wheel CO_2 emissions through electrification of LDVs, electricity carbon intensity needs to be less than 700-750 g CO_2/kWh, which is around India's level of CO_2 intensity today. As a result, indirect and displaced emissions from EVs nearly offset each other, resulting in a small negative impact on increasing CO_2 emissions in 2019. Nonetheless, in the STEPS the robust renewables deployment in the power sector expected over the coming decades results in India's EV fleet saving about 5 Mt CO_2 annually by 2030, compared with an equivalent fleet of ICEs. By 2040, electricity carbon intensity could fall below that of most European countries today, and a growing EV fleet could save more than 35 Mt CO_2 annually.

The speed at which the power sector reduces its CO_2 intensity is essential to the mitigation potential of large-scale EV deployment. If the power mix does not shift towards low-carbon sources as currently planned and remains as carbon-intensive as in 2019, this could negate CO_2 emission saving potential and lead to the EV fleet emitting 20 Mt CO_2 more than with an ICE fleet in 2040. In contrast, accelerating power sector decarbonisation could lead to greater emissions savings of 35 Mt CO_2 as soon as 2030.

Maximising the air quality and climate change mitigation benefits of transport electrification

Road transport electrification offers the unique opportunity to realise air pollution reduction in densely populated areas while delivering CO_2 reduction benefits. To ensure long term benefits, EV deployment must be paired with both tight emissions standards for ICEs and coal-fired plants and a rapid shift towards renewable energy sources in the power generation mix.

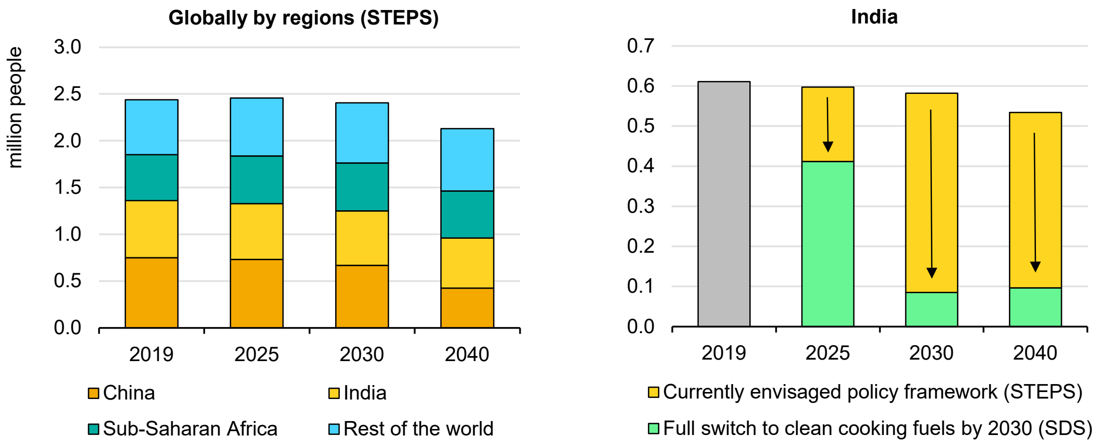
The impact of transport electrification considering the estimated impact of advanced vehicle emissions standards (BS VI) and the power sector's revised emissions standards, 2015 provide insights for optimising the benefits of electrification. First, deployment of EVs will help tackle NO_X emissions in urban areas immediately. Second, implementing tighter environmental regulations in thermal power plants will be imperative to avoid a potentially large increase in SO_2 emissions. Third, significant delays to shifting the power mix towards lower-carbon fuels will limit the CO_2 reduction benefits of electrification; EV deployment could swing from delivering savings of more than 35 Mt CO_2 annually to increasing CO_2 emissions by 20 Mt CO_2 in 2040, depending upon the speed at which the power sector lowers its CO_2 intensity. Finally, under the current policy framework, oil still accounts for 90% of road transport related energy use in 2040. Therefore, the implementation of tighter emissions standards for conventional vehicles, such as BS VI, is equally important in the short- and medium-term to address air pollution.

Chapter 4. Clean cooking

Clean cooking benefits population health

The IEA estimates that nearly half of India's population relied primarily on traditional biomass, such as wood, dung or agricultural residues in 2019. Burned indoors in poorly ventilated space, such fuels expose individuals directly to indoor air pollution, with severe consequences for their health. Globally, indoor air pollution led to almost 2.5 million premature death cases in 2019, a quarter of which took place in India (Figure 4.1).

Figure 4.1 Indoor air pollution related premature deaths in in millions, 2019-2040



Source: IIASA and IEA analysis.

The problem is well known and understood by the Government of India (GoI), which has developed a comprehensive policy framework to promote clean cooking solutions in the past decade, particularly targeting poor, rural households. Its flagship policy, the Pradhan Mantri Ujjwala Yojana (PMUY) programme, increased liquefied petroleum gas (LPG) coverage for low-income households to 83 million connections, helping to reach 99% of India's households as of January 2021. However, universal use of clean cooking fuel remains a challenge; the IEA estimates that around 660 million people, just under half of India's population, continue to rely primarily on traditional uses of biomass for cooking and heating in 2019. Current policy efforts can avoid increases in India's indoor air pollution-related premature deaths despite robust future population growth, but the toll remains high with more than 0.5 million cases annually until 2040. Achieving universal adoption of modern cooking fuel by 2030 could reduce incidents by more than 85%, to fewer than 0.1 million cases. Universal use of clean cooking fuel unlocks important further benefits in addition to the health benefits of reduced air pollution. These include socio-economic development objectives, such as improving women's wellbeing, who are disproportionately exposed to household air pollution and associated health impacts and reducing women's 'time poverty' associated with spending time collecting fuel. In addition, enhancing clean cooking access might help mitigate climate change: while switching from traditional biomass to less-polluting fossil fuels increases GHG emissions slightly, it can reduce black carbon (BC) pollution, a highly potential climate forcer.

Policy landscape

India's extreme poverty rate fell between 2011 and 2017 by about 23%, to reach around 10% of the population living on less than USD 1.90 per person per day. Nonetheless, many households continue to rely on traditional biomass and inefficient cook stoves and suffer high levels of unhealthy indoor pollution. In this context, the GoI promotes clean cooking through biogas, liquefied petroleum gas (LPG) or improved cook stoves. Focussing on LPG, the Pradhan Mantri Ujjwala Yojana (PMUY) programme is the GoI's flagship programme to promote access to clean cooking solutions. Between 2008 and 2017, the PMUY and preceding smaller programmes helped to more than double the registered, domestic LPG connections to reach 263 million. As of January 2021, the GoI reports that 99% of India's households have an LPG connection.

While LPG has been available since 1950, it was largely unused in rural households. The government began subsidising LPG use in the 1970s, but mainly middle- and upper-income households benefitted. From 2010 onwards, the GoI, together with national oil-marketing companies, revised strategies and started targeting women living below the poverty line. Along with the PMUY programme, the Give it Up campaign and the Pratyaksha Hastaantarit Laabh (PAHAL) scheme were established.

The **PMUY Scheme** was launched in 2016 to help below poverty line households get LPG access for cooking. It targeted women from deprived households, given the importance of female empowerment for social and economic benefits and household health. As the primary barriers to adoption of LPG remain its high upfront and refill costs, the government subsidises INR 1 600 (USD 23) to state-owned fuel retailers for every new LPG gas connection that includes a cylinder, pressure regulator, booklet and a safety hose. Households below the poverty line are also entitled to purchase a stove and refill with an interest free loan as part of the scheme.

Initially, PMUY aimed at providing free LPG connections to 50 million households living below the poverty line. This target was achieved within two years, and increased to 80 million connections, achieved by September 2019. This increased the LPG coverage to deprived households to nearly 95%, a sharp rise from less than 60% in 2015.

To divert funds to poorer households as part of the PMUY programme, the GoI likewise launched the **Give It Up campaign** in 2017, to 'nudge' relatively privileged households into giving up their subsidies. It was an immediate success, with 10.5 million people voluntarily giving up their subsidies. The government also made the subsidy unavailable to households with a taxable annual income of more than INR 1 million (USD 14 200).

The 2014 **PAHAL scheme** helps secure funds for the PMUY programme by reducing illicit use of subsidised LPG outside the non-household sector. It does so by directly transferring the subsidies to households within the PAHAL scheme, who must first buy LPG cylinders at market price.

The GoI also promotes **piped natural gas (PNG)** use within urban areas to reduce their LPG dependence and free up the fuel for rural areas. Towns across 400 districts have implemented or plan to implement PNG infrastructure, in line with government scale up plans to make it the predominant source of cooking fuel in urban areas. India has a long-term goal to move towards a gas-based economy and aims to have 15% of its primary energy demand coming from natural gas by 2030, from 6% today. To achieve this, investment in additional capacities for pipelines, gas infrastructure and distribution networks will need to be ramped up. Between 2008 and 2018, liquefied natural gas imports to India doubled, with most consumers in Delhi, Maharashtra and Gujarat. Currently, the power sector accounts for the bulk of the gas demand, but the existing city gas distribution is expected to grow rapidly and could contribute to 11% of the total demand for natural gas by 2030 as a result of government policies promoting the use of PNG. The GoI further plans a roll-out of more technical advanced cook stoves through their new Energy Efficient Cook Stove programme. The first phase of this new programme, implemented by the Energy Efficiency Services Limited, will provide consumers with 1 million energy efficient PNG based cooking stoves in selected cities throughout India. There is currently no national strategy to directly promote electricity-based cooking. The uptake of electric cooking stoves is linked to the government's target of reaching universal household electrification, achieved in 2019. However, reliability or quality of electricity supply, inconsistency in voltage and occurrences of black-outs are a technical hurdle to the adoption of electricity-based clean cooking, particularly in rural areas. Without further policy action, this challenge is likely to remain in the future. The IEA Stated Policies Scenario (STEPS) estimates that by 2040 fewer than 5% of households would use electricity for cooking. Nonetheless, the MoP launched the "Go Electric" campaign to increase awareness of the pollution, safety and efficiency benefits to electric cooking in February 2021.

Positive effects and limits of the current policy strategies

In 2019, about 660 million people still relied on the traditional use of solid biomass or coal as their primary cooking fuel. Nevertheless, India's share of the population primarily relying on biomass, kerosene or coal declined by almost 20% over the period between 2010-19, with half of the total population now using cleaner fuels such as LPG. While continued population growth makes attempts to rapidly decrease the number of people relying on biomass for cooking difficult, there has been clear progress and policy efforts are taking effect. Based on stated policies, the population share relying on the use of traditional biomass for cooking could drop initially to around 500 million or a third of India's population in 2030, and a quarter by 2040.

Building on successfully expanding LPG connections and coverage, the main challenge now is to ensure sustained use of LPG through tackling issues of adequacy, reliability, convenience, safety and affordability. Indeed, increased LPG connections do not directly translate to increased LPG usage. An average Indian household would require on average 93 kg per year to fulfil its cooking needs; however, the average annual refill consumption for a PMUY beneficiary was only about one-third this amount by the end of 2018. While there are many reasons for this, including culinary preferences and lack of information about health issues caused by traditional fuels, the main issues for PMUY beneficiaries remain availability and affordability. Only 41% of rural households receive home-delivery of LPG cylinders, while the median one-way distance to procure refills ranges from 2-7km, depending on the state, making LPG access cumbersome. Further, a 2019 review report by found that, although the high upfront cost of cookers is covered, of 31.8 million PMUY consumers with at least a one-year subscription, 17% of consumers never came back for a second refill and 33% used only one to three refills. Of those households that did not use LPG as a cooking fuel in 2016, 80% reported high recurring costs as the main barrier.

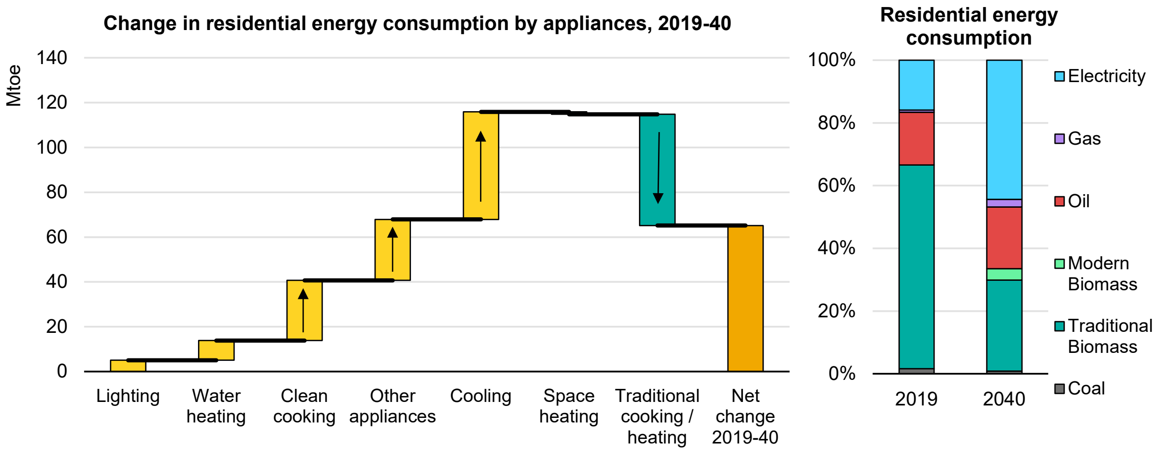
Trends and outlook

Residential sector

India's residential sector consumed 175 Mtoe of energy in 2019, making up almost 30% of the country's final consumption. Strong reliance on traditional biomass in residential buildings, consisting of fuelwood, agricultural residues, dung and charcoal, has been declining over the past decade. While traditional biomass still accounted for 65% in 2019, this is down from nearly 80% in 2005.

Looking forward, in the STEPS population growth gradually raises residential buildings' final energy use by 25% to about 220 Mtoe in 2040. Economic and technological development further changes the sector's energy mix. Use of traditional biomass declines by almost 45% until 2040, accounting for 30% of final energy consumed in the residential sector. Electricity surges to meet demand, more than tripling its current share to more than 40% by 2040, while LPG use increases slightly to meet 20% of demand. Modern biomass, solar installations and natural gas accounts for a small share of consumption after 2020 as well (Figure 4.2).

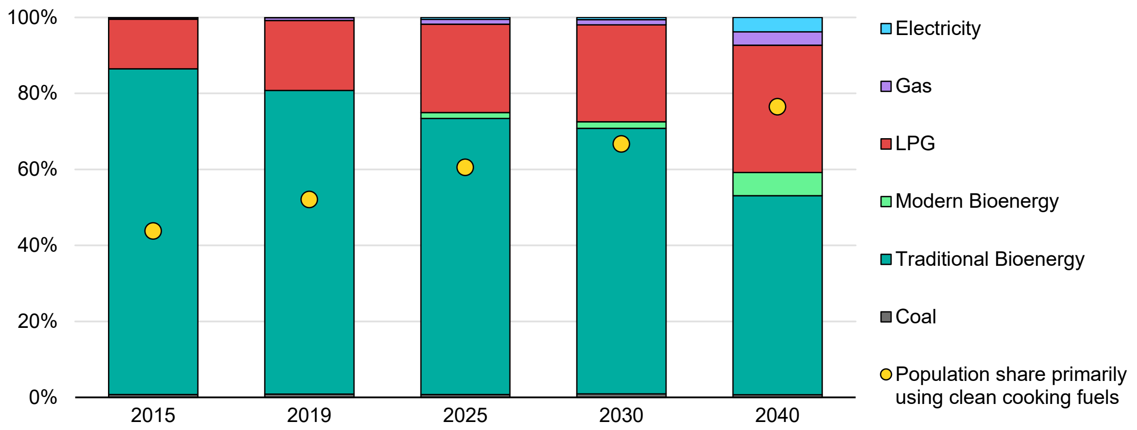
Figure 4.2 Changes in energy demand in residential buildings in the Stated Policies Scenario, 2019-2040



Cooking activities

Fully distinguishing residential energy consumption by specific activities is difficult as the use of traditional biomass usually simultaneously serves needs for cooking, hot water and space heating. Further, the large majority of India's households practise fuel stacking, meaning that they rely on several fuels, both clean and polluting. Cooking accounted for approximately three quarters of residential energy consumption in 2019, assuming 90% of residential consumption of traditional biomass was used for this activity. In the STEPS, the share of cooking activities decreases to 50% by 2040, given technological developments and current economic and social trends. In 2019, 80% of cooking activities were fuelled by traditional biomass, already 10 percentage points less than in 2010. LPG was in second place with 18%, while other forms of energy (electricity, gas and coal) played a negligible role. Current policies to promote access to modern cooking stoves are set to increase the uptake of clean fuels. In the STEPS, LPG consumption could increase about 55% until 2040, accounting for one-third of all cooking-related energy consumption. Other clean cooking fuels, including modern biomass or electricity could additionally deliver 13%. Despite this progress, traditional biomass might still account for over half of the fuel used for cooking in 2040 with another 1% based on coal (Figure 4.3).

Figure 4.3 Energy consumption in cooking activities by fuel in the Stated Policies Scenario, 2015-2040



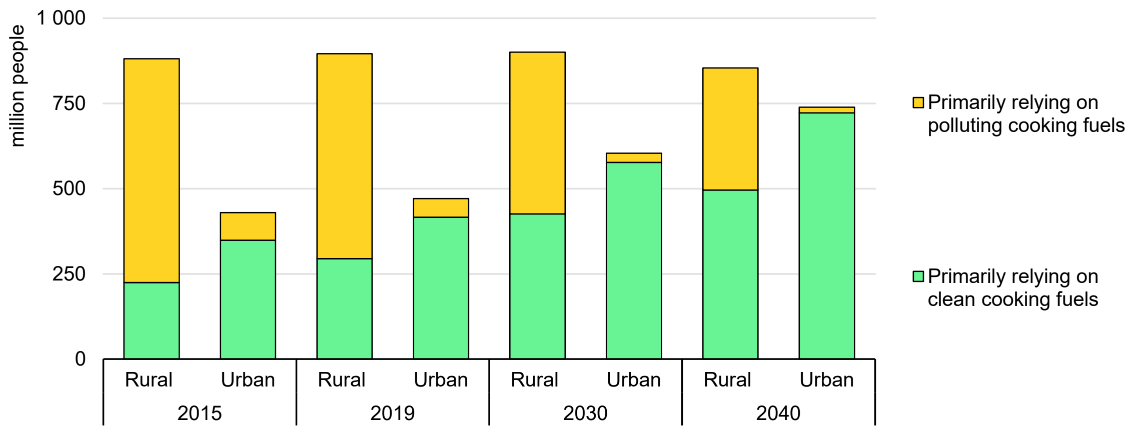
Note: It is assumed that 90% of residential biomass consumption is used for cooking activities.

Striking differences remain between urban and rural areas

The use of modern cooking fuel varies considerably between urban and rural areas. While nearly 90% of India's urban population relied on modern cooking fuel, two-thirds of the rural population still used mostly traditional biomass for cooking activities in 2019.

While India's population continues urbanising, increasing the share if urban population from one-third in 2019 to nearly 50% by 2040 in the STEPS, the country remains relatively rural in international terms. Current strategies to achieve universal access to clean cooking technologies are adapted to the geographical context, reflected in the potential fuel mix by 2040. While infrastructure for PNG will only be available in urban areas, the uptake of improved biomass and biogas would occur mostly in rural areas. Nonetheless, under the current policy framework, about 370 million people might continue to rely on traditional biomass in 2040, 95% of whom live in rural areas (Figure 4.4).

Figure 4.4 Population primarily relying on clean and polluting cooking fuels by area in the Stated Policies Scenario, 2015-2040

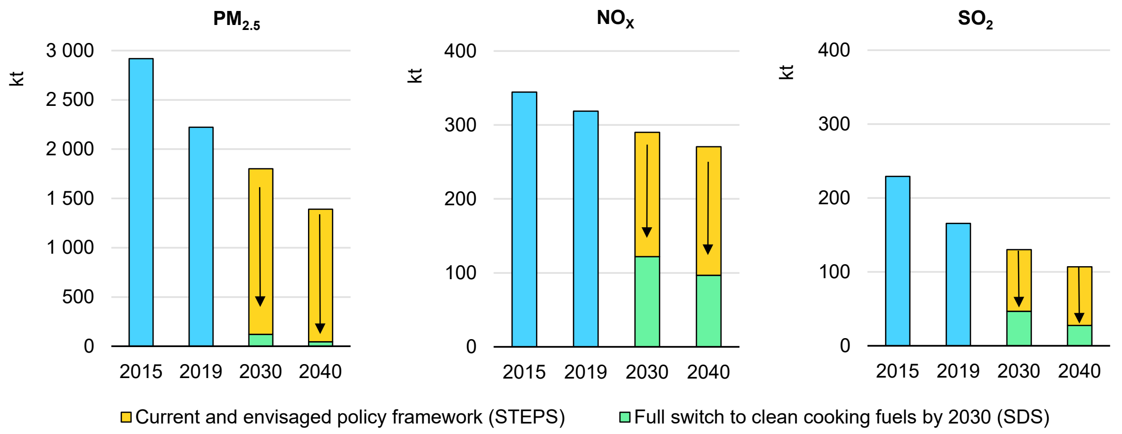


Impacts on air pollution of clean cooking

Indoor air pollution stems mainly from the heavy reliance on traditional biomass for cooking and heating, which causes high levels of harmful $PM_{2.5}$ pollution and contributes to a smaller extent to NO_X and SO_2 emissions. In 2019, India's residential sector emitted nearly two-thirds of the national $PM_{2.5}$ emissions from combustion activities, but less than 5% of NO_X and SO_2 emissions. Indoor air pollution occurs disproportionately in rural areas, where more than two-thirds of the population live without access to clean cooking.

Policies that reduce the use of traditional biomass in residential buildings already show positive effects on residential air pollutant emissions and are expected to continue to further reduce indoor air pollution in the future. Between 2015 and 2019, residential $PM_{2.5}$ emissions declined by a quarter to 2.2 Mt. Even with robust population growth, total residential $PM_{2.5}$ emissions could fall in the STEPS by 40% from 2019 to 2040, but with regional variations (Figure 4.5).

Figure 4.5 Residential indoor air pollution, 2015-2040



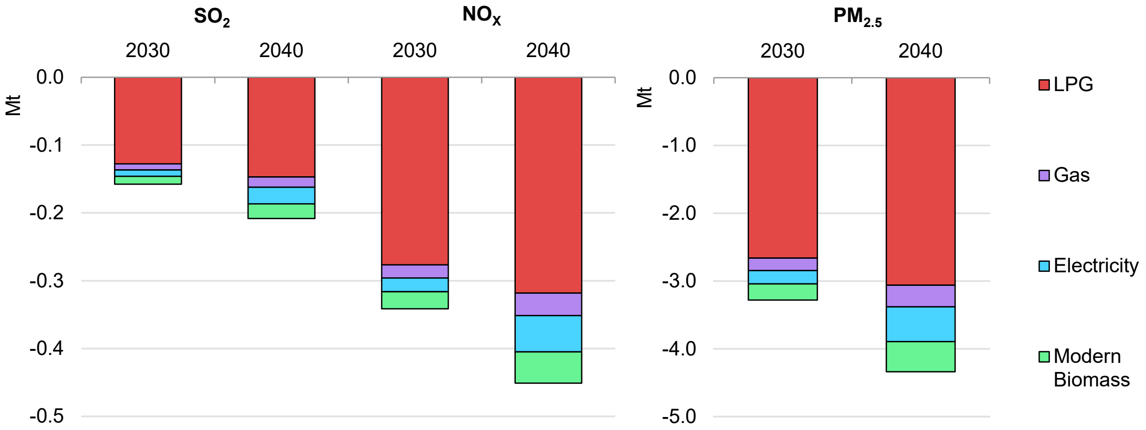
Source: IIASA and IEA analysis.

While the current policy framework already reduces indoor air pollution, it might not achieve a full switch to clean cooking fuel in the medium term. If India's population moved away from fuel stacking and fully switched to modern, clean cooking technologies by 2030, indoor $PM_{2.5}$ emissions could be nearly fully abated after 2030 and emissions from NO_X and SO_2 would be 65-75% lower in 2030 than under currently envisaged policies, reflected by the STEPS.

Nonetheless, the current policy framework could lead to a substantial amount of avoided indoor air pollution. Using clean fuels instead of traditional biomass can avoid annually 4.3 Mt $PM_{2.5}$ as well as 0.5 Mt NO_X and 0.2 Mt SO_2 in 2040. LPG realises about 70% of these avoided in both urban and rural areas. Additionally, air pollutant emissions are avoided in rural regions with modern biomass, while in urban agglomerations savings are realised by cooking with gas and electricity[1]. Urban areas account for about 60% of these avoided emissions (Figure 4.6).

[1] Indirect emissions from residential electricity consumption, occurring at the power plant level are not considered.

Figure 4.6 Avoided SO_2, NO_X and $PM_{2.5}$ emissions through switch to clean cooking fuels in the Stated Policies Scenario, 2030 and 2040

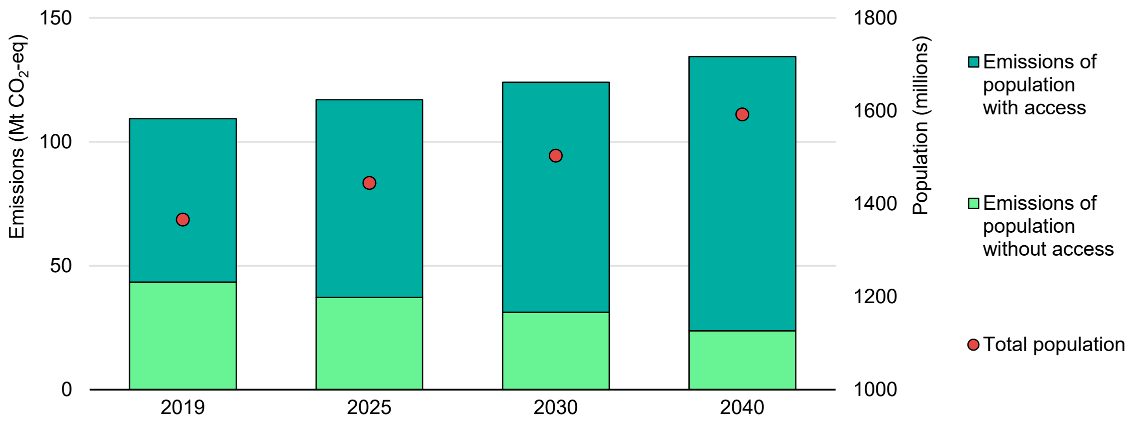


Climate impacts of clean cooking

The residential sector directly accounted for only 4% of India's CO_2 emissions in 2019, with oil contributing 85%. In the STEPS, higher per-capita GDP levels, population growth and urbanisation lead by 2040 to a tripling of urban floor space, resulting in higher energy demand and thus, an increase of nearly 50% in direct residential CO_2 emissions through fossil fuel combustion for cooking or heating. Increased electricity consumption in residential buildings further leads to greater indirect CO_2 emissions at the power plant level. In 2019, indirect CO_2 emissions were already three times higher than the residential sector's direct emissions. Household electricity consumption is expected to rise sharply in the future, driven by higher need for cooling and greater use of electric appliances. Despite reductions in electricity carbon intensity thanks to the power sector transition, this could mean indirect CO_2 emissions from electricity generation would increase by nearly 55% and make up more than three-quarters of total residential sector CO_2 emissions by 2040. However, this is a minor issue for cooking: even in 2040 less than 5% of India's population is expected to rely primarily on electricity for cooking.

Cooking fuel combustion causes several gas and aerosol emissions known to have a climate-forcing effect. Cooking activities generate three of six greenhouse gases (GHGs), namely CO_2, methane (CH_4) and nitrous oxide (N_2O). In contrast to air pollutants, GHG emissions do not have a direct local impact, and differentiating between rural and urban areas is therefore less relevant. Switching to clean cooking fuel saves substantial amount of CH_4 and N_2O emissions, generated through the combustion of biomass. However, while being clean, LPG and PNG remain fossil fuels and their consumption causes CO_2 emissions. Total cooking-related GHG emissions depend on assumptions on the CO_2 contributions of traditional biomass use. If harvested sustainably, biomass combustion can be considered as CO_2 neutral.[2] In this case total cooking-related GHG emissions were at nearly 110 Mt CO_2-eq. in 2019 and could reach almost 135 Mt CO_2-eq by 2040. With 75% of India's population (1.2 billion people) having access to clean cooking fuel in 2040, the associated GHG emissions would then make up for more than 80% of total GHG emissions (Figure 4.7). However, it is estimated that about 25% of fuelwood might be collected in an unsustainable manner. Already a 10%-share of unsustainably collected fuelwood for cooking could have emitted additional 30 Mt CO_2 from traditional biomass combustion in 2019 and might add about 20 Mt CO_2 in 2040.

Figure 4.7 GHG emissions from cooking activities in the Stated Policies Scenario, 2019-2040



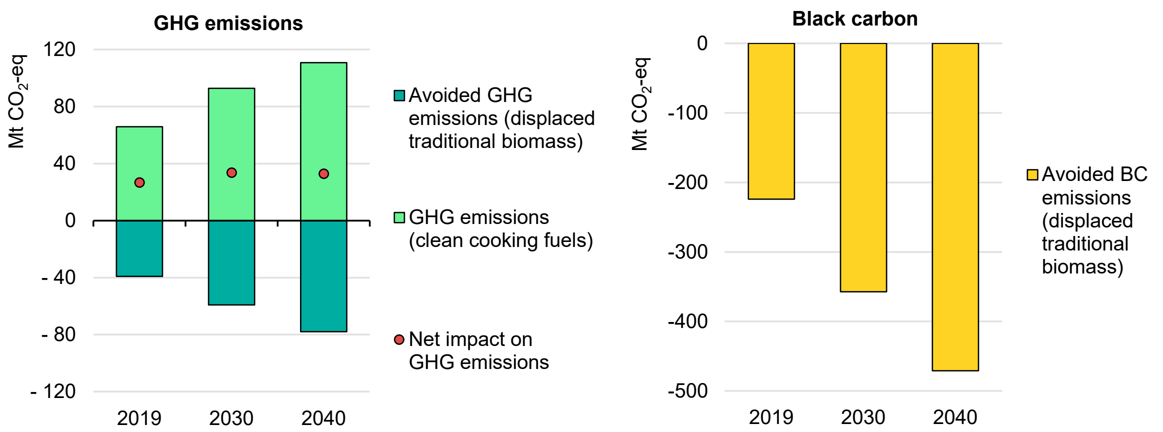
Note: GHG emissions are converted into CO_2-equivalents based on Global Warming Potentials with a 100-year time horizon based on Myre et al. (2013), IPCC.

The use of LPG and PNG for cooking generated more than 65 Mt CO_2-eq in 2019 and further uptake in the STEPS leads to a 68% increase to about 110 Mt CO_2-eq annually by 2040. With enhanced use of clean cooking fuel, the consumption of traditional biomass decreases. In 2019, displaced use of traditional biomass avoided 40 Mt CO_2-eq, with CH_4 accounting for almost 90%. Avoided emissions would rise to more than 80 Mt CO_2-eq in 2040. Thus, a switch to clean, but fossil cooking fuel increases GHG emissions by 25-35 Mt CO_2-eq annually.[3] Given that

[2] Current international convention exclude CO_2 released through biomass combustion is excluded from reported energy-related emissions, but estimated in the AFOLU sector. The release of CO_2 through biomass combustion is assumed to be balanced by the uptake of CO_2 during the feedstock's growth, resulting in zero net emissions within several decades.
[3] The comparison does not consider indirect emissions at the power plant level from residential electricity use.

fuelwood is not always collected sustainably and therefore could cause CO_2 emissions, this net increase in GHGs might potentially be overestimated.

Figure 4.8 Net impact on GHG and BC emissions of enhanced use of clean cooking fuel, 2019-2040



Note: GHG emissions are converted into CO_2-equivalents based on Global Warming Potentials with a 100-year time horizon based on Myre et al. (2013), IPCC.

Besides emitting the GHGs, incomplete burning of traditional biomass generates a substantial amount of black carbon (BC). India emitted through energy-related activities 1.02 Mt BC in 2010, largely stemming from the residential sector. This short-lived aerosol, often referred to as 'soot', is the most strongly light-absorbing component of PM. Although true extent and channels of black carbon's impact on climate change strongly vary by region and pose difficulties to directly compare it with traditional GHGs, research agrees that its characteristics might make BC a highly potent climate forcer. In 2019, cooking activities based on traditional biomass and coal emitted around 0.3 Mt BC; nearly 230 Mt CO_2-eq BC. Through enhanced uptake of clean fuels in the future, displaced consumption of traditional biomass could avoid 470 Mt CO_2-eq BC by 2040. Considering impacts of BC, a transition to clean cooking fuel is likely to contribute to climate change mitigation (Figure 4.8).

Maximising clean cooking access benefits

Policy efforts to improve access to clean cooking fuel are taking effect and are expected to reduce the share of the population using traditional biomass to less than 25% and enable a 40% reduction in indoor PM air pollution by 2040. Further, enhancing the use of clean cooking fuel might contribute to climate change mitigation through avoiding a substantial amount of black carbon emissions. Nonetheless, the high inequality in geographical distribution would remain, with 95% of India's population without clean cooking access living in rural areas in the future.

The main challenge is achieving sustained use of LPG and other clean cooking fuels through solving issues of adequacy, reliability, convenience, safety, and affordability. Shifting away from fuel stacking to only clean cooking fuels by 2030 would almost entirely remove indoor $PM_{2.5}$ emissions and reduce associated premature deaths to 0.1 million cases annually.

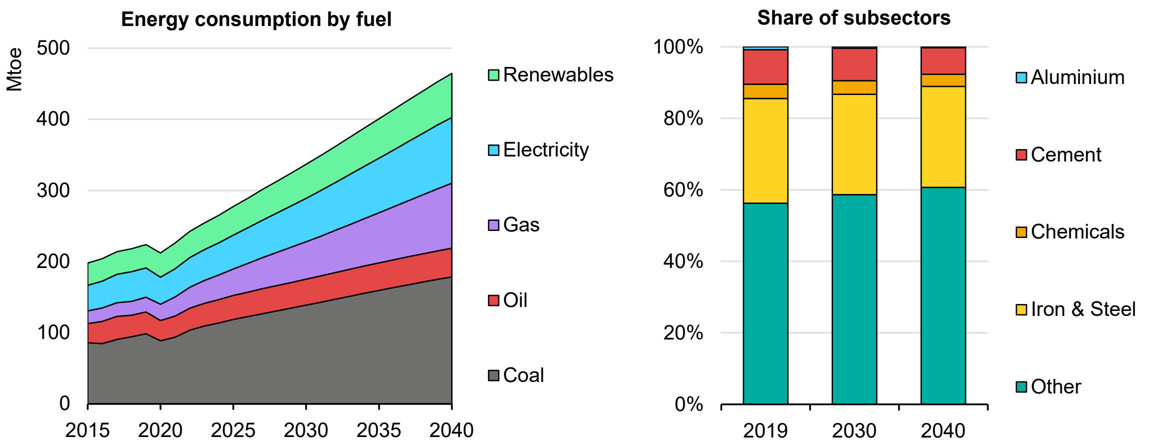
While fuel stacking itself is likely to remain in practice, it is crucial to focus on multi-fuel-based approach that ensures a "clean stack" of fuels, and may require looking beyond LPG. The PAHAL scheme already subsidises LPG purchases for PMUY beneficiaries; however, a primary difficulty is the need to purchase quantities of LPG in bulk, requiring payments that are difficult to manage with the income structure of poor households. In addition, the LPG bottling and distribution infrastructure is another barrier to refill, particularly over long distances, and cannot sustain the use of LPG by all households with a connection. Efforts to create new private distributors in rural areas are often hampered by low financial attractiveness. In urban areas, gas and electricity could be more significant in the future, freeing up LPG availability for rural areas. In major cities, improving gas stove availability and developing a gas distribution infrastructure would be beneficial. Furthermore, rapid improvements in household electrification suggest residential electricity use will strongly increase in the future. Overcoming reliability issues and improving the wattage of supply through investments in the power distribution infrastructure would allow electricity to actively contribute to clean cooking access in high- and middle-income urban areas. Finally, regional diversity will require policy makers to understand and account for geographic and cultural differences or similarities, and design solutions to improve access to cooking energy accordingly.

Chapter 5. Industrial energy efficiency

Industrial activities continue to experience exponential growth

The industry sector in India has experienced significant growth in the past two decades: triggered by a host of economic development policies, industry's contribution to GDP nearly quadrupled, resulting in considerable increase in energy demand growth in the sector. In 2019, industry was India's main energy-consuming sector, accounting for more than one-third of total final energy consumption (TFC) or nearly 225 Mtoe. Although small- and medium-sized enterprises (SMEs) accounted for more than half of industry TFC, three key sectors, iron and steel, chemicals and cement alone accounted for nearly 45%. In the Stated Policies Scenario (STEPS), industrial energy demand could more than double between 2019 and 2040, driven by strong growth in economic output in both large industries and SMEs and increase the industrial sector's share in TFC to 40% (Figure 5.1).

Figure 5.1 Industrial final energy consumption by fuels and sectors in the Stated Policies Scenario, 2015-2040



With output of 110 Mt in 2018, India became the world's second largest steel producer after China. The iron and steel sector is India's largest energy consumer in industry, requiring 65 Mtoe in 2019. It is dominated by companies with an annual steel production of above 5 Mt,[1] which account for more than 60% of the production. The GoI's National Steel Policy 2017 aims to double the sector's total capacity by 2030. This expansion will be driven by several key developments, including affordable housing construction;[2] infrastructure development, such as railway expansion, and the modernisation and development of ports with the SagarMala Programme; and automotive industry growth. In the STEPS, iron and steel output could exceed 300 Mt in 2040, increasing energy needs to 130 Mtoe, of which coal continues to fuel over 80%.

India is also the second-largest producer of cement in the world, after China, with output of nearly 340 Mt in 2019. Again, future requirements for new housing and infrastructure are expected to drive production higher, increasing cement output about 2.5 times until 2040. India's cement industry only consumed 10% of industrial energy demand in 2019. It is already one of the most energy efficient in the world as average capacity is relatively young and the latest production technologies such as dry process manufacturing have been adopted. Despite further enhancing efficiency of production processes, the cement sector's energy requirements could increase by 60% until 2040 in the STEPS. The chemical and petrochemical industry was the third-largest industrial energy user in 2019. By 2040, it could increase its energy consumption by nearly 80%. A key driver is the substantial growth in plastic demand and the "Make in India" programme, which promotes the production of plastics and fertilisers.

Given its structure, India's industry relies heavily on fossil fuels and will continue to do so in the future. In 2019, coal fuelled nearly 45% of industrial activities and oil and gas contributed together 23%. By 2040, fossil fuels could maintain a constant share of two-thirds in industrial energy supply, with coal's share decreasing to 38%, improving overall energy and carbon intensity.

The PAT scheme is key for reducing industrial energy intensity

Addressing energy demand in growing industrial sectors, and their relatively high reliance on fossil fuels, is a key area of policy focus for meeting climate and air pollution objectives (see chapter 2). India's Bureau of Energy Efficiency (BEE) found in its recent report, Unlocking National Energy Efficiency Potential, that the

[1] E.g. Arcelor-Mittal, the 1st main steelmaker in the world, producing 7 Mt in India, Tata Steel, the 9th steel producer in the world in 2019 with 30 Mt, or JSW Steel with 16 Mt.
[2] Pradhan Mantri Awas Yojana (Urban) Mission with the objective being to provide an affordable habitation for the whole urban population (Ministry of Housing and Urban Affairs, 2020).

industrial sector could contribute 60% of possible energy savings until 2031. To realise this potential, India has introduced several programmes under the National Energy Efficiency Mission (NEEM), focussing on industrial energy efficiency improvements. This is a key interest of the GoI, as reducing industrial energy intensity helps increase the economic competitiveness of key output sectors.

The Perform, Achieve and Trade (PAT) scheme is the country's flagship policy for industrial energy efficiency (Box 5.1). Launched in 2012 through the Energy Conservation Act, the PAT scheme is a market-based compliance mechanism that covers large energy users, so called designated consumers (DCs) from both the supply and demand sides. Each facility has an energy consumption reduction target; if not achieved, operators must either buy allowances from other DCs with consumption below their own target or pay penalties. The first PAT cycle, PAT I, (2012-2014[3]) included large energy-intensive industries such as iron and steel, aluminium, cement, chlor-alkali and fertilisers along with thermal power plants. After successfully completing this first cycle, BEE decided to continue and extend the scheme to further sectors and include additional DCs. From 2016 onwards, phases PAT II-VI have been rolled out annually in two-year cycles (Table 5.1).

Box 5.1 The Perform, Achieve and Trade (PAT) scheme

The PAT scheme was established in 2012 by the National Mission for Enhanced Energy Efficiency as India's flagship policy to boost energy efficiency of large energy consumers on both the demand and supply sides. It is a regulatory instrument that assigns a specific energy consumption reduction target in Tonnes of oil Equivalent (toe) for a two-year cycle to each listed user, so called Designated Consumer (DC). These targets are associated with a market-based compliance mechanism to enhance the scheme's cost effectiveness: If achieving excess energy savings, a DC obtains Energy Saving Certificates (ESCerts), that it can trade with non-attaining DCs. The ESCerts market is regulated by Central Electricity Regulatory Commission, and the Power System Operation Corporation (POSOCO) manages trading activities. Within 18 months of first notification, accredited auditors carry out mandatory energy audits to quantify energy savings. A penalty is attributed to DCs that did not achieve their target or failed to cover it with purchased ESCerts. Currently, the BEE is discussing the possibility to make ESCerts convertible to Carbon Saving Certificates.

[3] This period refers to India's fiscal year 2012-2013 – 2014-15.

To qualify as a DC, plants must meet minimum annual energy consumption levels, currently 0.03 Mtoe for thermal power plants and large industrial units, 0.003 Mtoe for textiles and 0.09 Mtoe for petroleum refineries. DC specific targets are calculated from their energy consumption, sector and fuel use in the base year, two years ahead of the respective cycle. Having successfully completed a first phase, the PAT scheme has been implemented since 2016 on a rolling-cycle basis, annually listing new DCs. PAT II to VI cover together 1073 DCs, which include plants for cement (16%), iron and steel (15%), chemicals (6%), textiles (14%) and thermal power (21%) as well as aluminium and paper, commercial buildings, railways, refineries and distribution companies (DISCOMs).

Overview of PAT scheme cycles

Cycles	DCs	Saving Target (Mtoe)	Achieved Savings (Mtoe)	Energy demand covered (Mtoe) (TPED Share)
PAT I (2012-14)	478	6.68	8.67	164.97 (24%)
PAT II (2016-18)	621	13.63	14.08	304.15 (36%)
PAT III (2017-19)	116	1.06	3.50	35.00 (4%)
PAT IV (2018-20)	109	0.70	-/-	-/-
PAT V (2019-21)	110	0.51	-/-	-/-
PAT VI (2020-22)	135	1.28	-/-	-/-
PAT II - VI	1073	17.18	*17.58*	*339.15*
Sectors covered	Since PAT I: Iron and steel, chlor-alkali and fertilisers, cement, aluminium, paper, textiles, thermal power plants Since PAT II: Refineries, railways, DISCOMs Since PAT IV: Petrochemicals, buildings (services)			

Besides the PAT scheme, BEE initiated three further programmes to boost industrial energy efficiency: The Energy Efficiency Financing Platform launched in 2015 and designed to foster financial institutions to invest in energy efficiency projects; the Market Transformation for Energy Efficiency, promoting adoption of energy efficient equipment and appliances through innovative business models; and the Framework for Energy Efficient Economic Development, promoting energy efficiency initiatives by hedging against investment risks. Furthermore, the National Resource Efficiency Policy incentivises investments in steel recycling technologies and a taxation on scrap imports above a defined threshold, with the goal to eliminate these imports and increase the recycling rate up to 90% by 2030.

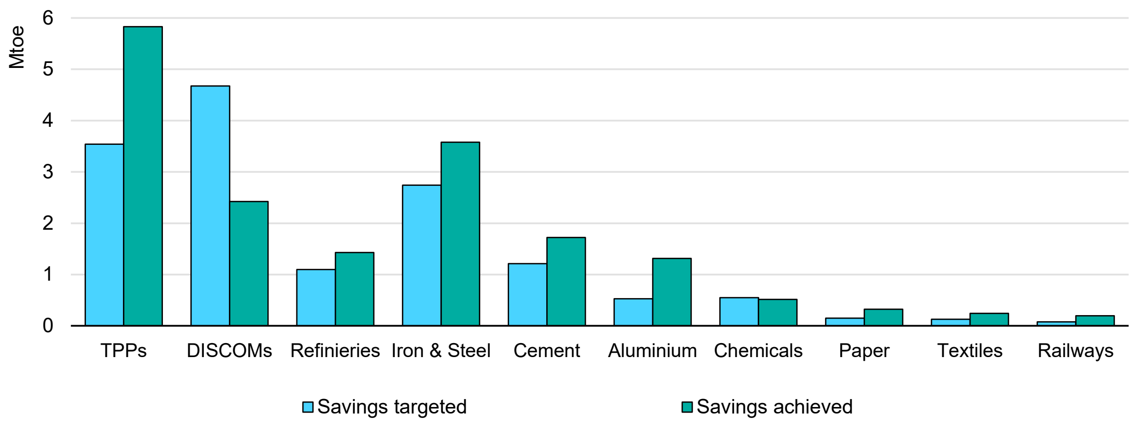
In addition to programmes for large industrial consumers, the BEE launched several further initiatives at the national level to foster energy efficiency improvements in the SME sector. It did so in recognition that the SME sector's lack of access to the latest technologies caused energy security, competitiveness and environmental concerns. The National Programme on Energy Efficiency and Technology Upgradation of SMEs, launched by the BEE in 2007 along with other initiatives, seeks to identify access to, and implement, advanced technologies and operating practices, such as LED lighting, waste-heat recovery solutions and tailored cooling devices. Although policy interventions have demonstrated the effectiveness of the energy efficient technologies, large-scale deployment of energy-efficient technologies in SMEs has been limited and further incentives to increase the voluntary uptake of energy-efficient solutions is required.

PAT scheme achievements

In March 2021, the BEE published a report achievements under PAT cycles II andIII. Taken together, PAT II and III covered about 340 Mtoe energy consumption, representing 40% of India's total primary energy demand (TPED) in 2014-15. The cycles targeted energy consumption savings of 14.7 Mtoe between 2016 and 2019, with large industry accounting for 35% and the supply side (thermal power plants, petroleum refineries and DISCOMs) for the majority of the remainder. With 17.6 Mtoe of savings achieved, these targets were exceeded by 20%.

During PAT II and III, large industries achieved energy savings of 7.5 Mtoe, 42% of total savings. While iron and steel, cement and aluminium industries largely overachieved targets, fertiliser producers fell short by about 15%. To realise these savings, for example, cement facilities focused on installation of waste heat recovery systems and vertical rolling mills, while the iron and steel sector invested in top recovery turbines and coke dry quenching process. On the supply side, savings were 9.7 Mtoe, or 55% of the total, surpassing their target by 4%. While thermal power plants fell 5% short regarding their target for PAT I (2012-2014) of 3.2 Mtoe, they surpassed PAT II and III targets by 65%, accounting for 5.8 Mtoe of savings. Most thermal plant energy efficiency improvements are realised through the use of washed coal, which burns longer, installation of waste heat recovery systems and steam turbine gas-based plants. Newly added DISCOMs, however, failed to meet their targets by nearly 50%, achieving only 2.4 Mtoe of the 4.7 Mtoe targeted. PAT IV to VI included more companies and sectors with 1073 DCs and, aggregated, nearly 375 Mtoe energy consumed (Figure 5.2).

Figure 5.2 Targeted and realised energy savings from PAT II and III (2016-2019)



Source: IEA analysis based on BEE (2021).

While over achievement of targets is a welcomed indicator of success, it could also suggest that the scheme was not ambitious enough. Targets could be set higher, by e.g. coverage widened to include more DCs and, potentially, sectors. It may be difficult to integrate SMEs that fall below current minimum energy consumption thresholds to qualify as a DC, and improving efficiency for SMEs would require well aligned additional policies.

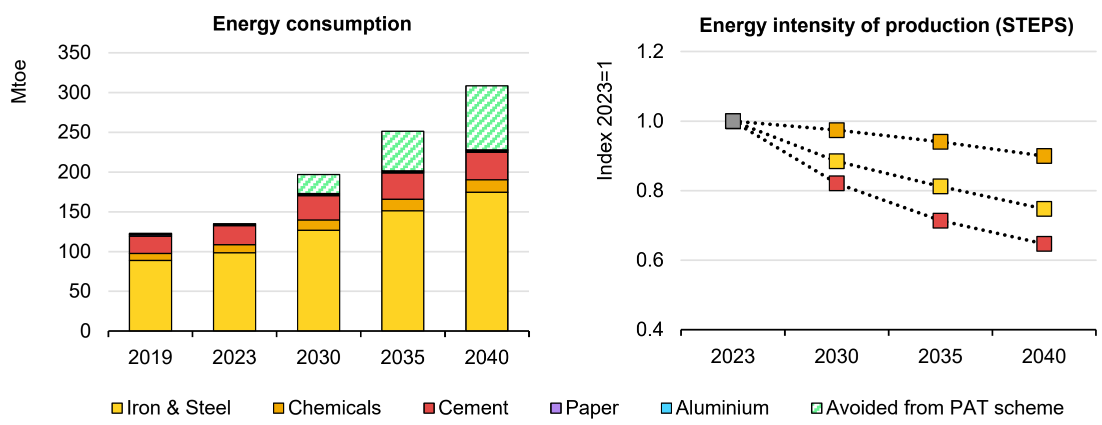
PAT continuation would contribute to further industrial energy consumption reductions

Extending and expanding the PAT scheme following the completion of PAT VI (2022) would enable significant energy consumption savings in large industries, notably in iron and steel, chemicals, cement, paper and aluminium. The IEA's STEPS assumes a continuation and widening of the PAT scheme in the industrial sector, which would enable a reduction in the energy intensity of production (Mtoe/Mt) in key output industries. Between 2023 and 2040, the energy intensity of iron and steel production could improve by 25%, chemicals by 10% and cement by 35%.

Nonetheless, owing to a 2.5 times higher output (Mt), energy consumption in India's large industries increases in the STEPS by 85% to 185 Mtoe by 2040 relative to 2019. Without policy incentives such as PAT to enhance their energy efficiency post-2023, large industries would further increase their energy requirements in the future. Additional energy needs for production could amount to 24 Mtoe in 2030 and 80 Mtoe in 2040. This would comprise a quarter of the potential total energy requirements of large industries in 2040. More than 70% of energy consumption savings in 2040 are realised in the iron and steel sector, while cement delivers an additional 25% savings (Figure 5.3).

Nevertheless, non-specified industries accounted for 55% of industrial energy consumption in 2019 and that share would increase to 60% by 2040 in the STEPS. Emphasising large industries only, therefore, will be insufficient if India is to capture the full potential of industrial energy efficiency improvements. The PAT scheme will need to be complemented and aligned with existing and new policies for SMEs.

Figure 5.3 Outlook for energy consumption of large industries in the Stated Policies Scenario, 2019-2040



Impacts to industrial air pollution

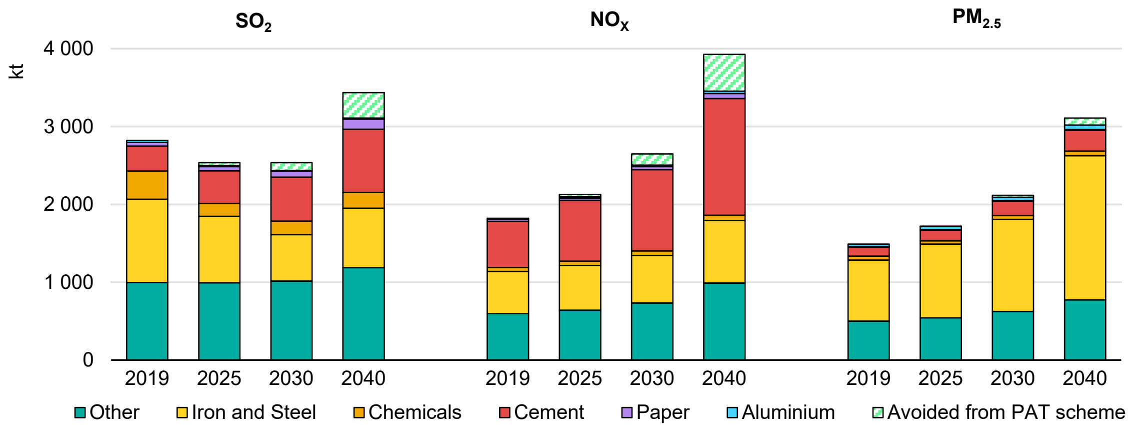
By improving energy efficiency and avoiding additional energy consumption in industry, the PAT scheme indirectly delivers environmental benefits as lower energy consumption results in fewer CO_2 and air pollutant emissions. In 2019, the industry sector, including production processes, emitted 2.8 Mt SO_2, 1.5 Mt $PM_{2.5}$ and 1.8 Mt NO_X. This accounts for one-third of total energy related SO_2 and $PM_{2.5}$ pollution and about one-fifth of NO_X emissions in 2019. Driven by industrialisation, these shares double to 2040 in the STEPS, by which time industry emits two-thirds of SO_2 and $PM_{2.5}$ (3.1 Mt SO_2 and $PM_{2.5}$) and half of total NO_X emissions (nearly 3.5 Mt NO_X).

Emissions standards for India's industrial sector build upon the Environment (Protection) Act (1986) and the Air (Prevention and Control of Pollution) Act (1981). They are developed and implemented by the MoEFCC and CPCB. As a recent example, the MoEFCC issued more restrictive emission standards for iron and steel producers at the end of 2019. While State Pollution Control Boards have the possibility to set tighter standards than the national ones, this rarely happens in practise. Developing industrial emission standards is generally a challenging process, as subsectors are heterogeneous with substantial variation in fuels, processes and products, requiring a high differentiation in standards.

If no further energy efficiency improvements are made post-2023, India's large industries would emit annually 0.33 Mt SO_2 and 0.47 Mt NO_X more than with additional energy efficiency measures. This means additional that air pollutant emissions which could have been avoided through energy efficiency measures make up about 14-16% of potential SO_2 and NO_X emissions from large industries. However, non-specified, smaller industries added about one-third total industrial air pollution across all pollutants in 2019, even though, this share would decrease to less than 30% for NO_X and $PM_{2.5}$ emissions in the STEPS (Figure 5.4).

It is important to note that industrial energy efficiency measures such as the PAT scheme can only target combustion-related air pollutant emissions, while they do not directly influence process-based air pollution. As industrial processes accounted for about 35-45% of NO_X and SO_2 and more than 75% of $PM_{2.5}$ emissions in 2019, the impact of energy efficiency measures is measurable but inherently limited. To tackle these emissions, policies like the PAT scheme need to be combined with measures to enhance material and resource efficiency.

Figure 5.4 Air pollutant emissions by industry in the Stated Policies Scenario, 2019-2040



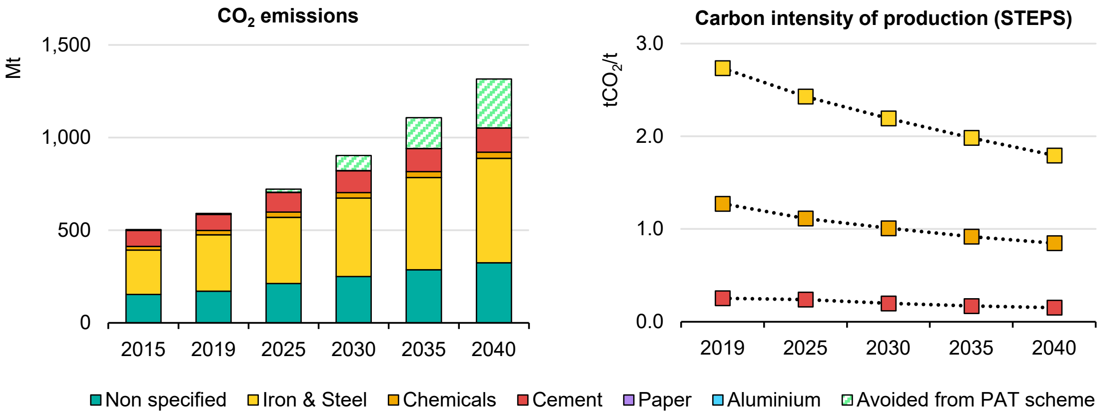
Source: IIASA and IEA analysis.

Impact on industrial CO_2 emissions

India's industrial sector generated 590 Mt CO_2 in 2019, a quarter of total CO_2 emissions. Energy-intensive industries, such as iron and steel, chemicals and cement contributed 70% of this amount. Emissions continue to rise in the future as industrial output grows at a faster rate than that at which industries decarbonise their production processes: by 2040, industry emits around 1050 Mt CO_2, of which large industry accounts for 730 Mt CO_2 (70%). Between 2019 and 2040 (STEPS), iron and steel along with the chemicals sector could reduce their carbon intensity of production by a third, to 1.8 t CO_2/t and 0.8 t CO_2/t respectively, and cement by as much as 40% to 0.2 t CO_2/t (Figure 5.5).

The GoI's BEE estimates that all DCs included in PAT I saved 31 Mt CO_2 while PAT II and III saved 87 Mt CO_2 between 2016 and 2019. The largest contributions to PAT II and III savings were the thermal power, iron and steel and cement sectors. Continuing the PAT scheme in the future could result in substantial CO_2 emissions savings. If the scheme is continued and expanded to include additional DCs, IEA analysis estimates that more than 80 Mt CO_2 emissions could be avoided in 2030 and 265 Mt CO_2 in 2040, of which iron and steel would contribute about 70% and cement more than 25%. Converting the PAT scheme's energy saving certificates to carbon saving certificates could further trigger fuel switching, which in return would save additional CO_2 emissions.

Figure 5.5 Industrial CO_2 emissions and carbon intensity in the Stated Policies Scenario, 2015-2040



Maximising environmental benefits of industrial energy efficiency

The industrial sector accounted in 2019 for a quarter of India's CO_2 emissions (590 Mt CO_2) and contributed one-fifth of NO_X and one-third of SO_2 and $PM_{2.5}$ pollution. Large industrial consumers, namely iron and steel, chemicals and cement, strongly rely on fossil fuels for production and thus account for the majority of industrial emissions, with approximately two thirds of air pollutants and CO_2 emissions. These three sectors undergo tremendous growth, increasing their production about 2.5 times between 2019 and 2040 in the STEPS resulting in a doubling of industrial fossil fuel consumption over the same period. A continuation and expansion of the PAT scheme could be a key policy to curb future growth in industry-related emissions through increasing the sector's energy efficiency. The PAT scheme could avoid through 2040 265 Mt CO_2, a fifth of total potential industrial CO_2 emissions in that year as well as more than 14-16% of SO_2 and NO_X pollution from large industry by 2040. Conversion of energy savings certificates to carbon saving certificates could provide further incentives for fuel switching, triggering additional CO_2 emissions reductions.

Nonetheless, strongly reducing the environmental footprint of India's industrial sector requires measures in addition to the PAT scheme. Besides targeting energy efficiency of heavy industry, policy makers need to focus on their material efficiency. Assuming a continuation of the PAT scheme, CO_2 emissions from industry are projected to increase by nearly 80%, pollution from NO_X and $PM_{2.5}$ almost to double by 2040 in the STEPS. [Material efficiency gains](), however, offer the potential to further reduce this level of emissions by helping decrease demand for materials, complementing efforts to change the means by which materials are produced through energy efficiency improvements, fuel switching and the adoption of new low-carbon process routes, including the potential use of hydrogen. In the iron and steel sector, for example, increasing metal scrap collection and sorting rates, enabling higher shares of recycled production, which is less energy and emissions intensive than production using virgin materials. In the case of cement, reducing the clinker-to-cement ratio is key to improve materials efficiency during manufacturing, as clinker production is the most emissions intensive part of production. While common cement typically contains more than 90% clinker, it is possible to replace a considerable portion of alternative constituents, such as fly ash or granulated blast furnace slag. This makes more efficient use of clinker and substantially reduces the environmental footprint of cement. Finally, efforts in non-specified industries need to be further developed and implementation strengthened as well as aligned with energy and material efficiency policies for heavy industries.

Acronyms and abbreviations

BC	Black carbon
BEE	Bureau of Energy Efficiency
CEA	Central Electricity Authority
CPCB	Central Pollution Control Board
CPP	Captive power plants
DISCOM	Distribution company
EESL	Energy Efficiency Services Limited
EV	Electric vehicle
EVI	Electric Vehicle Initiative
FAME	Faster Adoption and Manufacturing of Electric
FDG	Flue-gas desulphurisation
FGD	Flue-gas desulphurisation
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies model
GDP	Gross domestic product
GHG	Greenhouse gas
GoI	Government of India
HDV	Heavy-duty vehicles
ICE	Internal combustion engines
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
LDV	Light Duty Vehicles
LPG	Liquefied petroleum gas
MoEFCC	Ministry of Environment, Forest and Climate Change
MoP	Ministry of Power
NAAQS	National Ambient Air Quality Standards
NCAP	National Clean Air Programme
NCT Dehli	National Capital Territory of Delhi
NEEM	National Energy Efficiency Mission
NEMM	National Electric Mobility Mission
PAHAL	Pratyaksha Hastaantarit Laabh
PAT scheme	Perform, Achieve and Trade scheme
PM	Particulate matter
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped natural gas
SME	Small and medium-sized enterprises
STEPS	Stated Policies Scenario
TERI	The Energy and Resource Institute
TFC	Total final energy consumption
TPED	Total primary energy demand
WEM	World Energy Model
WEO	World Energy Outlook

Units of measure

CO_2	carbon dioxide
g CO_2/kWh	tonne of carbon dioxide per megawatt hour
Gt	giga tonnes
GW	gigawatt
kt	kilo tonnes
kWh	kilowatt hour
Mt	million tonnes
MW	megawatt
MWh	megawatt hour
NO_X	nitrogen oxides
$PM_{2.5}$	particulate matter 2.5
SO_2	sulphur dioxide
TWh	terawatt hour

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