Transitioning India's Road Transport Sector

Realising climate and air quality benefits

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Abstract

India aims to reach net zero carbon emissions by 2070 – a demanding task given the country's ambitious sustainable development objectives. Road transport currently accounts for a relatively small share in national CO_2 emissions, but as India seeks to satisfy the mobility needs of its growing, urbanising and rapidly developing population, energy demand and CO_2 emissions from the sector could double by 2050, locking in emissions and putting at risk the achievement of the long-term climate goal.

This report, the product of a collaborate effort between the International Energy Agency (IEA) and India's public think tank NITI Aayog, provides a detailed picture on how CO_2 emissions from road transport are likely to grow under existing policies and compares these projections with a pathway that could bring the sector on track with the 2070 goal. It discusses various policy options that the country could assess if it is to accelerate the shift to sustainable road transport, focussing on the benefits that energy efficiency improvements and a switch to cleaner energy sources can bring. The report also quantifies the co-benefits a rapid decarbonisation of road transport can bring in terms of tackling air pollution – one of India's most pressing environmental challenges.

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Executive summary

Road transport will play a key role in India's clean energy transition

India is among the fastest growing economies globally and will soon become the world's most populous country. While road transport expansion and improvement typically serve as a catalyst for socio-economic development, as has happened in many countries, it has unleashed several negative environmental problems in India, namely, burgeoning emissions of CO_2 as well as air pollutants such as nitrogen oxides (NO_X) and fine particulate matter ($PM_{2.5}$).

Road transport presently accounts for 12% of India's energy-related CO_2 emissions and is a key contributor to urban air pollution. As India seeks to meet the increasing demand for private mobility and the transport of goods, energy use and CO_2 emissions from road transport could double by 2050. The IEA's Stated Policy Scenario (STEPS), which reflects the trajectory implied by today's policy framework, projects that both energy demand and CO_2 emissions will peak in the 2040s and decline only marginally afterwards. The steadily increasing use of private cars and the expanding truck fleet, with continued reliance on gasoline and diesel, drive the rise. Two-wheelers continue to dominate India's vehicle fleet, but due to fast electrification, their energy needs and emissions start to decline in the mid-2020s.

Ambitious policies could reduce energy demand by 30% and avoid 60% of the expected CO_2 emissions in 2050

In 2021, India's Prime Minister announced the ambition to reach net zero carbon emissions by 2070. According to the IEA's Announced Pledges Scenario (APS), which brings the sector on track with the 2070 goal, ambitious policies could help reduce energy demand by 30% in 2050 relative to current policies, saving India 70 million tonnes of oil equivalent (80% of the sector's current energy needs). CO_2 emissions peak in the mid-2030s and fall to about 20% below today's level by 2050. Cumulatively, this could avoid up to 4 Gt CO_2 between 2021 and 2050, compared to the current policy framework. Up to 2030, additional reductions are realised equally through stronger energy efficiency improvements in vehicles with an internal combustion engine (ICE), accelerated electric vehicle (EV) uptake and higher biofuel use. After that, electrification, especially of cars and trucks, accounts for most of the additional abatement potential.

Electrification is a key pillar of India's strategy to decarbonise transport

India is the world's fourth largest car manufacturer, making EVs a potential source of economic growth and exports. There are two flagship national programmes to support road transport electrification in India: The Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme, which provides purchase incentives and charging infrastructure support until 20, and the Production-Linked Incentive (PLI) schemes that provide incentives for manufacturing in different sectors. Numerous state-adopted policies complement national programmes.

As a result of these policies, EV sales are projected to reach nearly 35% of total vehicle sales in 2030. To bring the sector on track with the 2070 goal, this share needs to reach 50%. The amount of CO_2 that EVs can avoid will depend on the speed at which India decarbonises its power sector, which currently heavily relies on coal. Today, the tailpipe CO_2 emissions that India's EV fleet avoid are roughly equal to the CO_2 emissions that such vehicles indirectly cause at the power plant level. However, this is set to change in the future: By 2030, India's EV fleet will avoid around 5 Mt CO_2, while in 2050, the amount could range from 110 to 380 Mt CO_2, depending on the EV fleet size and the pace of power sector decarbonisation. EV deployment can also considerably reduce citizens' exposure to air pollution.

Two- and three-wheelers are the frontrunners for electrification

India's EV market is small but growing. EVs accounted for 1.8% of new vehicle sales in 2021, and more than 4% in 2022. Shares vary from more than 50% among three-wheelers, to 4% for two-wheelers and less than 1% for cars, reflecting differences in purchase and operating costs. Analysis of the total cost of ownership (TCO) shows that electric three-wheelers are 70% cheaper than their gasoline-powered ICE equivalents over their lifetime. EVs are also cost competitive in other categories, but high upfront costs can deter consumers. India's policies are addressing this: for example, the sales price of electric scooters was about three times that of a comparable gasoline scooter in 2022, but the FAME subsidy and favourable taxation reduce this difference to twice as expensive. Policy measures such as low-emission zones, stringent fuel economy standards or zero-emission vehicle (ZEV) requirements can further accelerate EV deployment.

Fuel efficiency improvements are equally important

Even in the APS, gasoline and diesel still account for more than half of the road transport sector's energy demand in 2050, highlighting the critical importance of improving fuel efficiency in conventional vehicles. India implemented the

Corporate Average Fuel Consumption (CAFE) standards for passenger cars in 2017 and in 2022, these standards were tightened by more than 10% to 113 g CO_2/km. It is expected that manufacturers will meet this target largely by means of flexibility mechanisms that aim to promote technological innovation . Fuel economy standards for trucks were adopted in 2017.

In the STEPS, the fuel efficiency of cars improves by less than 20% up to 2035. In the APS, however, it improves by more than 50%. A speedy update and gradual tightening of its fuel economy standards would help India achieve this. If India were to achieve a 55% reduction in corporate average fuel economy by 2035 compared to current levels (i.e., imitating the EU Fit for 55 target with a five-year time lag), cars sold between 2035 and 2037 could save up to 145 Mtoe in fuel consumption and avoid 400 Mt CO_2 emissions over their lifetime compared with the current policy framework. India could further consider adopting fuel economy standards for two-wheelers, given that they account for more than half of the country's gasoline consumption.

Developing strategies for clean trucking is a priority

Improving the fuel efficiency of diesel trucks will be pivotal in limiting future diesel demand and emissions growth. The government is revising fuel economy standards for trucks and is expected to release a roadmap by the end of 2023. To be on track with the 2070 goals, the fuel efficiency of the diesel truck fleet needs to improve by more than 35% by 2050. The largest additional abatement potential in the APS however lies in the deployment of ZEV trucks, i.e., electric and fuel cell trucks. While ZEV trucks make inroads into the fleet only after 2030, policy efforts to reduce costs and build enabling infrastructure need to begin now for leveraging scale in the next decades. To achieve this, India could build on the successful April 2022 tender with FAME through which 5 450 electric buses will be introduced across the country. Implementing a similar procurement for medium-sized electric freight trucks could avoid 3 Mt CO_2 and more than 30 kt NO_X emissions over the replaced trucks' lifetime.

The co-benefits for air quality are considerable

Air pollution is one of India's most pressing environmental challenges. Of the 50 most polluted cities in the world, 35 are in India. Reducing transport-related emissions would have direct public health benefits, given that a large share of emissions occurs in urban areas and close to the ground, directly affecting millions of people. Road transport currently accounts for 20-30% of urban air pollution.

India regulates vehicle tailpipe emissions by means of the Bharat Stage (BS) emission standards. In April 2020, India implemented BS-VI standards, which largely parallel Euro-6/VI norms, leapfrogging from BS-IV to BS-VI in only three years. In addition, several climate-driven policies, including vehicle electrification, have strong co-benefits for air quality and public health. In the STEPS, NO_X emissions from road transport decline by 15-20% by 2030 and fall drastically afterwards, due to the BS standards and the gradual shift to EVs. However, non-exhaust $PM_{2.5}$ emissions caused by the suspension of road dust, and brakes and tyre wear abrasion increase and require greater attention.

India's scrappage policy of 2021 has great potential to reduce air pollution. This policy requires passenger cars older than 20 years and commercial vehicles older than 15 years to pass a "fitness test" to keep their registration. The replacement of freight trucks which fail the test could avoid up to 17% of NO_X and 11% $PM_{2.5}$ emissions from trucks, assuming that they would be replaced by trucks that are BS-VI compliant.

Strengthening enabling conditions for the transition

Holistic long-term planning can support the fast and ambitious transition of the road transport sector. As in other countries, transport planning and policy making in India has largely been conducted by mode, partly because responsibilities are split between various institutions. The last significant review of India's transport planning dates to 2010. Launching another round of long-term planning could help provide a common vision for the sector, support policy alignment and provide certainty to industry, financial markets and consumers. Improving data on key indicators such as vehicle activity and performance, energy use and emissions would support such efforts.

Achieving an ambitious transition will require mobilisation of capital and finance. The average annual investments in EVs and private chargers will need to increase from about USD 210 million in 2016-2020 to USD 19-33 billion in 2026-2030, depending on the scenario. However, regulatory uncertainty, high risk-perception, and limited risk mitigation options and targeted financing mechanisms are increasing the costs of finance, while hampering access to funds. Options to address these barriers range from data and capacity improvements to policies which reduce upfront and financing costs (e.g., through subsidised interest rates) as well as the use of guarantees or risk-sharing facilities, and the promotion of innovative business models.

The shift from petroleum products to electricity will have consequences for public finances, especially at the state level, where the taxes on petroleum products contribute 3% to 12% of net revenue receipts. By 2030, the shift from ICEs to EVs could lead to USD 5-8 billion in foregone tax revenue from avoided gasoline and diesel consumption at the state level. Additional tax revenue from EVs' consumption of electricity compensates only half of the forgone revenue.

Alternative revenue streams could be secured, for example, by shifting from taxing fuel consumption to taxing vehicle use by means of road pricing.

Following steps could help realise further climate and air quality benefits

- **Strengthening policies for electrification.** Continue existing demand incentives to help bridge the upfront price gap between EVs and ICEs beyond 2024 (when FAME will expire) and maintain favourable taxation. As electric three-wheelers are already highly cost competitive in TCO terms, fleet targets, ZEV sales requirements or registration restrictions for ICEs could be considered. For cars, demand incentives will need to be accompanied by stringent fuel economy standards. Preferential parking and low-emission zones can provide an additional push for EV adoption, without increasing the burden on public budgets.
- **Strengthening fuel economy standards.** Establish a roadmap for fuel economy standards in line with long-term climate goals and with a regular revision cycle. Consider EU fuel economy regulations with a five-year time lag, e.g., aiming for a 15% improvement by 2027, applying penalties for non-compliant car manufacturers, and updating flexibility mechanisms. Introduce standards for two-wheelers, sufficiently stringent to support electrification.
- **Supporting the transition of heavy-duty vehicles.** Continue to prioritise the deployment of electric buses by means of bulk procurement. In trucking, update and enforce fuel economy regulations. In addition to ongoing efforts to improve freight transport logistics, India could support pilot projects for electric and fuel cell trucks and expand demand incentives to ZEV trucks.
- **Fully implement the scrappage policy** to accelerate phase-out of the most polluting vehicles. Rapidly setting up more testing centres could help accelerate the identification of end-of-life trucks. Strengthening incentives to scrap and replace, and linking them with access to finance, and a public communications campaign, could further enhance the policy's potential to reduce air pollutants. In addition, and building on the National Clean Air Programme, cities can reduce circulation of the most polluting vehicles in densely populated areas, e.g., by establishing low-emission zones.
- **Strengthen policies and mechanisms to improve access to EV financing and reduce the cost of financing.** Opportunities include enhancing technical capacities in the financial sector, improving data availability on long-term EV performance, promoting risk mitigation mechanisms and businesses models that reduce financing needs and/or costs, and including EVs in priority sector lending.
- **Strengthening the basis for transport policy making.** Develop a long-term plan to align road transport with the national 2070 net zero goal, including milestones and measures on how to achieve them. Invest in collecting and managing road transport-related data to support policy making. Strengthen institutional structures, for example, by creating a nodal agency for EV policies, to strengthen policy coordination across sectors and levels of government.

- **Strengthen international engagement and collaboration.** India already participates in several international collaborative efforts such as the Clean Energy Ministerial's Electric Vehicle Initiative and the CALSTART initiative. India should take advantage of the opportunities that exist to further strengthen international collaboration and improve co-ordination in ways that will contribute to progress towards its long-term goals.

Introduction

India faces the dual challenge of accelerating its transition to a low-emissions road transport sector, while meeting the surge in private mobility demand and steady increase in freight activity linked to a growing, urbanising and rapidly developing population. Road transport currently accounts for only 12% of India's energy-related CO_2 emissions, but the sector's emissions are projected to more than double by 2050 under current policies. In 2021, India's Prime Minister announced the ambitious goal to achieve net zero carbon emissions by 2070. To bring the sector in line with this goal, the IEA estimates that road transport emissions need to peak in the mid-2030s and fall below today's levels by 2050. Such a scenario would also deliver benefits in terms of air pollution – one of India's most pressing environmental challenges.

This report, prepared at the request of and in co-ordination with NITI Aayog's Vertical for Infrastructure Connectivity, aims to shed light on the likely trends in CO_2 and air pollutant emissions from road transport. Using projections modelled for the IEA's *World Energy Outlook 2022*, it explores how road emissions are likely to develop under existing policies; and compares those projections with a pathway that could bring the sector on track with the 2070 goal. Based on IEA scenario comparison, additional quantitative analysis, stakeholder consultations and literature review, this report discusses policy options that could help put the sector on track with India's net zero goal in a way that meets India's economic, social and environmental development aspirations. While recognising that a successful road transport transition will require curbing the sector's activity growth and shifting mobility demand to other transport modes, this report focuses on the benefits that energy efficiency improvements and a switch to cleaner energy sources within the road transport sector can bring. The report is structured into four chapters.

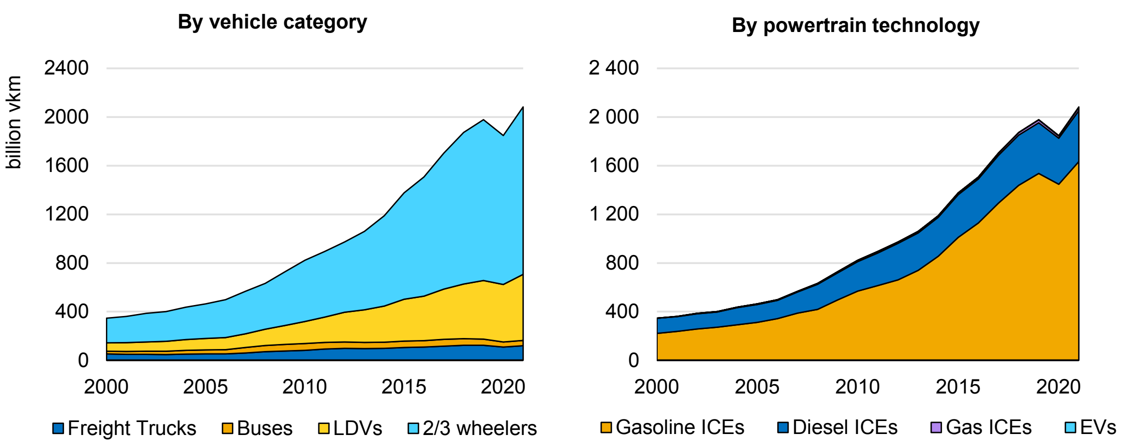
- Chapter 1 outlines the key features of road transport in India.
- Chapter 2 presents India's policy framework for road transport, as well as key policy measures shaping the sector's environmental performance.
- Chapter 3 identifies where policy gains are highest in terms of energy savings and avoided emissions by comparing an IEA benchmark scenario with an alternative scenario that would bring the sector on track towards its 2070 goal.
- Chapter 4 discusses selected policy levers that could help accelerate India's road transport transition. These include options to strengthen transport policy making, to raise fuel economy standards, to improve support policies for vehicle electrification, to reduce emissions from trucking, and to reduce the impact of road transport on air quality.

Chapter 1. India's road transport

Roads account for roughly 90% of passenger and 70% of freight movement in India (TERI, 2021). The expansion of the economy, growing population, rising income levels and urbanisation have driven up demand for road transport services and infrastructure in the country. India's population grew by 1.3% annually between 2000 and 2021, while per-capita income increased by 5.1%. The share of the urban population increased from 28% to 35% during that period. Road transport activity has grown more than six-fold since 2000, with increasing demand and improved access to mobility. The Covid-19 pandemic reduced road transport activity in 2020 (by 7% compared to 2019), but it quickly rebounded in 2021 to levels exceeding those seen prior to the pandemic (Figure 1.1).

India's road network extends to more than 6.3 million kilometres, making it one of the most extensive in the world (MoRTH, 2022a). Road density (the length of the road network relative to land area) is higher than that of most IEA member countries (ITF, 2022a), but it varies considerably across states. About 70% of the total road length is rural roads. Road quality can be poor, especially in rural areas, while urban road networks can suffer from high levels of traffic congestion. Public transport systems vary in quality and inter-modal integration can be limited. Active mobility modes (such as walking and cycling) play an important role, despite limited infrastructure.

Figure 1.1 Road transport activity by vehicle category and powertrain technology, 2000-2021



Note: LDV = Light-duty vehicle. LDVs mostly include passenger cars, as well as a smaller number of light commercial vehicles.

Key features and fleet composition

Passenger transport

While there has been an increase in the use of all vehicle types, the growth in the use of two-wheelers has been the highest in absolute terms (Figure 1.1). As in other Asian countries, passenger mobility is characterised by a high penetration of motorised two-wheelers, which account for nearly 75% of the total number of registered vehicles in India (MoRTH, 2022b). Two-wheelers are an attractive option for motorised mobility owing to lower purchase and operating costs compared to cars, and their ability to navigate through congested cities. Almost 50% of Indian households own a motorised two-wheeler (IIPS and ICF, 2021). India's market for two-wheelers is one of the largest in the world, with sales exceeding 20 million per year before the Covid-19 pandemic (SIAM, 2022).

Three-wheelers (motorised auto-rickshaws) also play an important role in urban mobility in India. Although they account for a small share of total vehicle registrations (under 3%), the distances driven are comparatively high, reflecting their importance for both cargo (i.e., last-mile delivery) and passenger services. Three-wheelers often fill the gap created by insufficient or unreliable public transport services. They also act as a feeder for other modes of transport and, in some cities, operate as taxis and provide transport to school.

Passenger cars account for a relatively minor share of total road transport activity, around 20% of vehicle kilometres (vkm). Only 7.5% of households own a car. However, the car fleet is growing rapidly, increasing from 6 million vehicles in the year 2000 to an estimated 42 million in 2021. India has one of the fastest growing passenger car markets, with annual sales exceeding 3 million vehicles before the Covid-19 pandemic (and remaining close to 3 million in 2020-22) (SIAM, 2022). The car ownership rate has doubled in a decade to 30 cars per 1 000 inhabitants in 2021. If two- and three-wheelers are included, the motorisation rate rises to nearly 200 vehicles per 1 000 inhabitants, which remains below that of most advanced economies as well as Indonesia (363), Brazil (265) and Mexico (206).

Public transport plays an important role in India, accounting for nearly 30% of trips in urban areas and even higher shares in larger cities such Mumbai (44%) and Kolkata (57%) (Abhishek, 2020). Currently, two-thirds of the population live in rural areas, but cities are rapidly expanding, with the urban population increasing by around 2.3% per year. Formal city bus systems are available in most larger cities. In addition, informal private operators provide bus services on certain routes, including in cities with formal public bus systems. More than 90% of India's bus stock is owned and operated by private operators. Overall, India's bus stock is small compared to the country's population, about 24 buses (public and private) per 100 000 inhabitants, below national and international standards on bus service provision of 40-60 buses (WRI India Ross Center, 2021). Metros currently operate in 18 cities, and various new metro projects are being planned (The Economic Times, 2022a). The integration of metros and suburban rail with other public transport infrastructure remains a challenge. This fact, along with the poor quality of the public transport infrastructure and low frequency of services, are identified as key barriers to higher public transport use (CEEW, 2019).

Intermediate public transport plays an important role in India. In larger cities, they provide the first- and last-mile connection to mass transit stations, such as metro and suburban rail or rapid bus transit systems. They are also very common in smaller cities, where trip distances tend to be shorter and public transport infrastructure less developed. Intermediate public transport is mostly provided by three-wheelers and, to a lesser extent, taxis and cycle rickshaws (ITF, 2021). Motorcycle taxis are also gaining prominence, notably among female passengers due to higher perceived safety (Thakur, Jain and Harikumar, 2020).

Non-motorised transport plays an important role in urban transport. About 40% of urban trips are 5 km or less, and people usually walk or cycle for such trips (CEEW, 2019). Half of households across the country own a bicycle, while a quarter own no mode of transport, meaning that they are dependent on walking and public transport to meet their mobility needs (IIPS and ICF, 2021). People using non-motorised transport often do so because they cannot afford motorised transport. Most Indian cities lack appropriate networks of walkable sidewalks or cycling lanes, but action is increasingly being taken to change this. In Chennai, for example, over 100 km of pedestrian-friendly streets were introduced across the city between 2015 and 2020 (MoHUA, 2020). During the pandemic, the usage of public transport (bus and metro) services declined sharply, in favour of cars and two-wheelers. Surveys indicate that the use of private taxis and active mobility such as cycling also increased (Thakur, Palak et al., 2020).

Freight transport

Freight trucks (above 3.5 tonnes [t]) account for over 80% of road freight traffic (ITF, 2021). Within the truck fleet, medium-sized vehicles play a more important role than in most advanced economies, which partly reflects the quality of the road network. Light commercial four-wheelers (below 3.5 t) have a limited modal share in India, as commercial transport also relies on three-wheeled auto rickshaws. In more recent years, following the boom in e-commerce, two-wheelers have become an important mode for last-mile deliveries.

Freight transport in India is highly fragmented, with about 75% of the market being run by small owner-operators who own less than five trucks (NITI Aayog, RMI India and RMI, 2021). Only 10% of the market is run by fleet operators who own more than 20 trucks. This makes it difficult to monitor and regulate freight trucks.

The transport industry has, however, become more structured over time, with an increasing share of larger fleet operators and this trend is expected to continue.

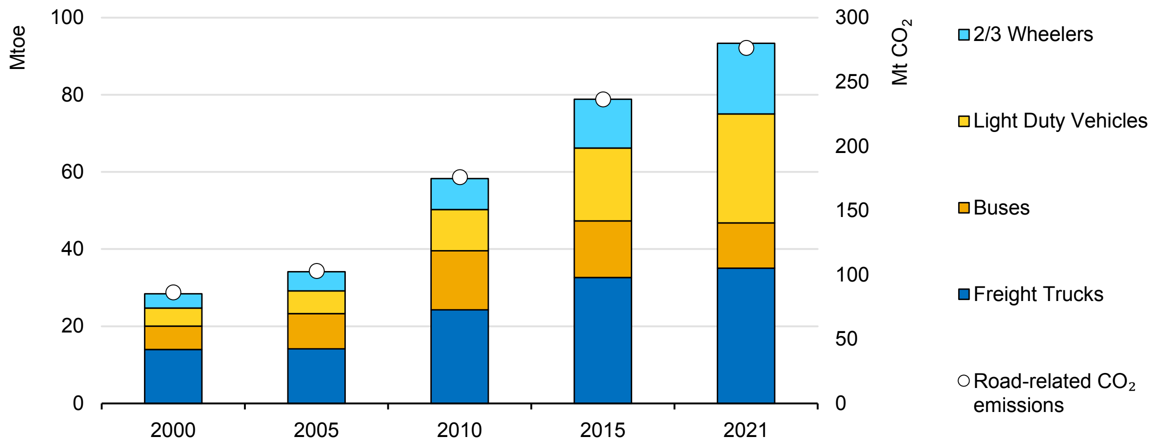
Energy use and CO_2 emissions

Mobility demand growth and rising motorisation rates have led to a surge in India's road transport-related energy demand and associated CO_2 emissions. In 2021, road transport accounted for 14% of total final energy consumption, lower than the global average of 20%, and that of other emerging economies such as Indonesia (30%) or Mexico (38%). The relatively low share is partly explained by the substantial use of inefficient traditional biomass in the residential sector, (accounting for 15% of final energy consumption in 2021) which inflates the country's total final energy consumption. Road transport makes up for 92% of all transport-related energy demand and 94% of transport-related CO_2 emissions, with domestic aviation, rail and domestic shipping contributing the remainder.

Oil products, i.e., gasoline and diesel, are the dominant energy source, meeting 95% of the sector's demand. Road transport is the largest oil-consuming sector in India (accounting for 44% of final consumption in 2021) and it is the fastest growing. Other sources, i.e. natural gas, electricity and biofuels, still play only minor role.

In absolute terms, both energy demand and CO_2 emissions from road transport have more than tripled since 2000 (Figure 1.2), with freight trucks and passenger cars each contribute about one-third of the respective increase. In 2021, trucks accounted for 38% of both fuel consumption and CO_2 emissions, and cars for one-quarter. While two- and three-wheelers represented 80% of the vehicle stock, they accounted for only 20% of energy demand and emissions. Their share in energy demand and emissions has risen constantly over the 2010s. Overall, road transport accounted for 12% of national CO_2 emissions from fossil fuel combustion in 2021. Per-capita emissions from the sector increased by a factor of 2.5 from 2000 but remained 50-75% below per-capita emissions in other emerging economies such as Brazil, China, Indonesia or Mexico.

Figure 1.2 Road transport fuel consumption and related CO_2 emissions, 2000-2021



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Air pollution and associated health impacts

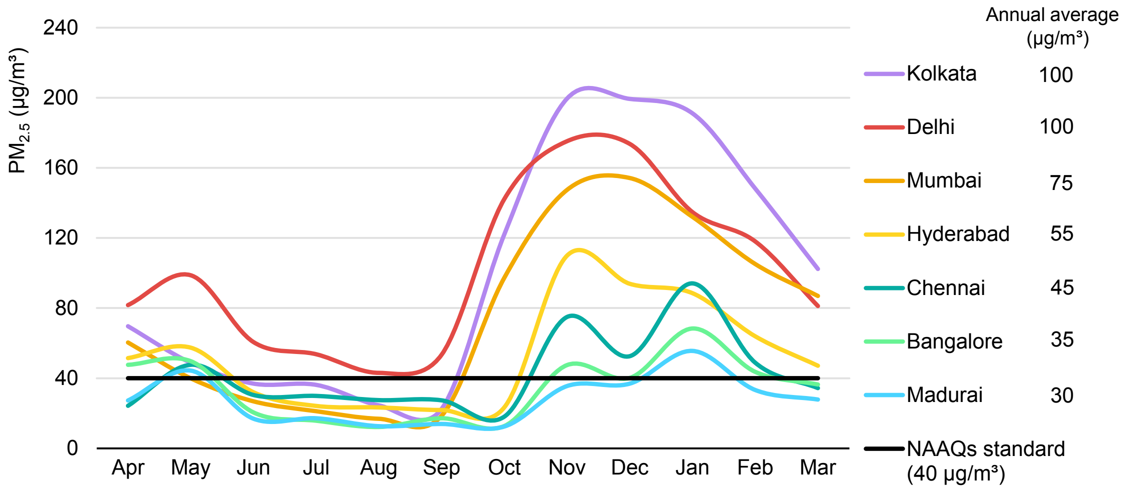
Air pollution has emerged as one of India's gravest environmental problems and tackling it has therefore become a policy priority in recent years. About 70% of the country exceeded the recommended national annual average concentration level of 40 µg/m³ of fine particulate matter ($PM_{2.5}$) in 2019 (IEA, 2021a).[1] Of the 50 most polluted cities in the world, 35 are in India (IQAir, 2021). While India's air pollution is perennial and affects the entire country, northern states suffer from particularly high concentration levels, especially in winter. The Indo-Gangetic Plain in northern India, including the National Capital Territory of Delhi, experiences $PM_{2.5}$ annual mean concentrations of over 80 µg/m³ (Singh, N. et al., 2021) (Figure 1.3).

While geographical and meteorological conditions contribute substantially to high $PM_{2.5}$ concentrations, pollution sources are overwhelmingly anthropogenic. These include the burning of crop residues in late autumn, in particular in northern India, but energy-related activities, including road transport, are a major cause as well. Vehicles greatly add to primary nitrogen oxides (NO_X) and particulate matter pollution, including by means of non-exhaust activities, such as road dust suspension (Box 3.2). The contribution of road transport to local air pollution is notably high in urban areas. A recent study found that in Bangalore, transport accounts for 40% of $PM_{2.5}$ pollution, while soil dust, partially suspended by vehicles, accounts for another 25% (CSTEP, 2022). In Delhi, the contribution of vehicles to ambient $PM_{2.5}$ concentration was estimated at 20-25% in winter and

[1] The WHO recommends an air quality of $PM_{2.5}$ of 5 µg/m³ as annual average (WHO, 2021).

6-9% in summer (ITT Kanpur, 2016). As vehicle tailpipe emissions occur close to the ground near pedestrians, urban transport emissions have a sizeable impact on public health.

Figure 1.3 Monthly ambient $PM_{2.5}$ concentration in selected Indian cities, 2019



Note: NAAQs = National Ambient Air Quality Standards.
Source: TERI and IEA analysis for IEA, 2021a.

Economic and socio-economic impacts

With limited domestic oil resources, growing transport activity and associated fuel consumption has steadily increased India's dependence on crude oil imports over the past two decades. India is one of the largest oil importers globally, importing 85% of crude oil to meet its energy needs. In 2020, the crude oil import bill reached USD 62 billion; in 2021 it nearly doubled to USD 119 billion, reflecting soaring global crude oil prices (The Economic Times, 2022b).[2]

The rapid growth of India's vehicle fleet has furthermore contributed to considerable traffic congestion. In 2021, the three largest Indian cities (Mumbai, Bangalore and New Delhi) ranked among the world's 20 most congested cities (TomTom, 2022). In all three cities, an average trip took approximately 50% longer than it would in uncongested conditions. The economic costs resulting from congestion in these three cities were estimated at about USD 20 billion. These costs stem from fuel waste, productivity losses, traffic crashes and air pollution (Financial Express, 2018).

[2] 2020 data refers to the fiscal year 2020/21, spanning 1 April 2020 to 31 March 2021. This convention is different from the one used by the government of India, in which 2020 data would refer to 1 April 2019 to 31 March 2020.

Road safety remains a key concern in India. The country accounts for about 10% of road crash fatalities worldwide with about 150 000 deaths in 2016 (WHO, 2018). Road crashes cost the Indian economy an estimated 5-7% of GDP each year (World Bank, 2022). More than half of the victims are pedestrians, cyclists, or motorcyclists. Lower income and vulnerable households bear a particularly high burden; they are more likely to be traffic crash victims, and more affected by any associated income loss and medical expenses.

Chapter 2. Policy framework

This chapter summarises the most relevant goals, strategies and policies that impact the Indian road transport sector. The first two sections briefly present India's policy on climate and air pollution control, while the third section provides a more detailed overview of the policy and institutional framework for road transport. It outlines the main policy instruments affecting the sector's environmental footprint, including those promoting electrification, energy efficiency improvements, alternative fuels and air pollution control, and outlines the current tax regimes for vehicles, fuel and road use.

National targets for climate and air quality

Climate change mitigation

At COP26 in November 2021, India's Prime Minister announced the ambition to achieve net zero carbon emissions by 2070 (MEA, 2021), and stated new 2030 targets, including: i) reducing the greenhouse gas (GHG) emissions intensity of the economy by 45% below the 2005 level; ii) increasing non-fossil capacity in power generation to 500 GW (i.e. tripling capacity from 2021); iii) meeting 50% of electricity capacity from renewable energy sources; and iv) reducing the amount of carbon that India is projected to emit in this decade by one billion tonnes.

In August 2022, the new emissions intensity target of a 45% reduction by 2030 was included in India's updated Nationally Determined Contribution (NDC). According to the new submission, the update is a step towards India's long-term goal of reaching net zero emissions by 2070. India's first NDC of 2016 contained a GHG emissions intensity target of 33% to 35% below 2005 levels by 2030 (UNFCCC, 2022). Under its first NDC, India identified a set of mitigation strategies for clean energy and energy efficiency across different sectors, including industry, electricity, buildings and transport. Many of these strategies build on the 2008 National Action Plan on Climate Change (NAPCC), India's early effort to create a consolidated climate action plan. The NAPCC outlined potential policies and programmes directed at climate change mitigation and adaptation through eight national missions, several of which have since been updated (MoEFCC, 2008).

Reducing transport sector emissions is one of eight priority areas included in India's NDC. Emissions reductions are expected to be realised by vehicle electrification, enhanced fuel efficiency, the use of alternative low-carbon fuels, and modal shift in passenger and freight transport. These focus areas, in addition to demand and traffic management and intelligent transport systems, are identified as key enablers in India's Long-Term Low-Carbon Development Strategy, published in November 2022 (MoEFCC, 2022a). The NDC and long-term strategy, however, do not specify concrete emissions goals for sectors.

Air pollution control

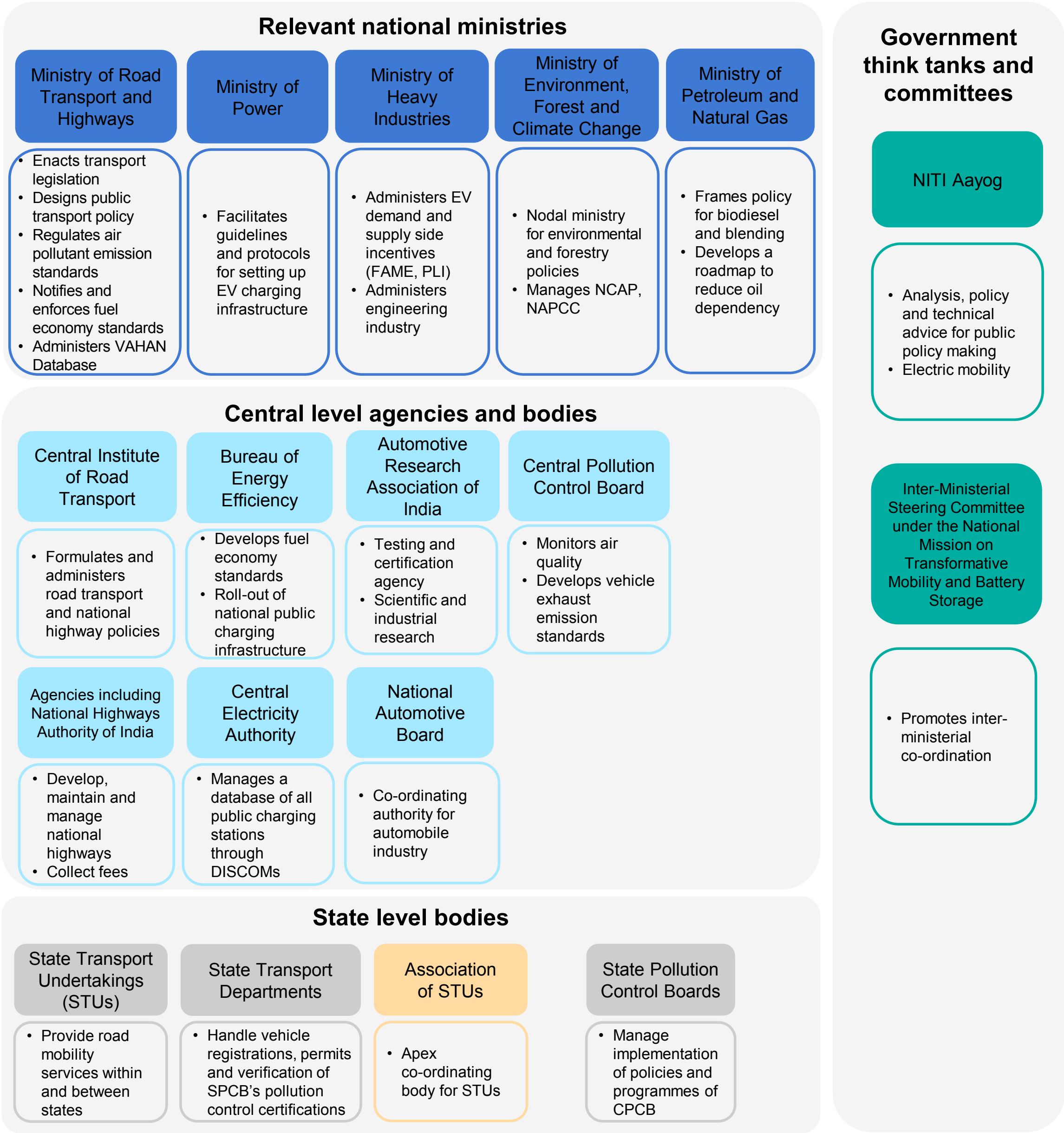
India's flagship programme for better air quality is the National Clean Air Programme (NCAP), launched in 2019 (MoEFCC, 2019). By 2024, India aims to reduce PM concentrations 20-30%, compared to 2017 levels in 131 targeted cities under the NCAP.[3] The programme required these cities to develop City Clean Air Plans that list sector-specific interventions with predetermined timelines and implementation responsibilities. Most cities have developed such a plan and transport commonly plays a central role in them: about half of the actions identified in city plans aim to tackle transport emissions and road dust suspension (Ganguly, T., K. Selvaraj and S. Guttikunda, 2020). The NCAP furthermore aims to strengthen the national air quality monitoring network, build capacities for air pollution management, reduce vehicular and industrial emissions, and increase public awareness about the hazards of air pollution. Sectoral plans and initiatives provide additional frameworks and measures to address air pollution. In transport, this includes most notably standards that regulate the emission of air pollutants in motor vehicles (see below).

Policy and institutional framework for road transport

India does not have an overarching strategy or policy framework for road transport. India's transport policy making is a concurrent function between national, state and local governments. At the national level, key institutions include the Ministry of Road Transport and Highways (MoRTH), the Ministry of Power (MoP), the Bureau of Energy Efficiency (BEE), the Ministry of Heavy Industry (MHI), the Ministry of Environment and NITI Aayog (Figure 2.1). Bodies such as the Inter-Ministerial Steering Committee under the National Mission on Transformative Mobility and Battery Storage aim to promote inter-ministerial co-ordination. At the state level, the State Transport Departments are the main bodies implementing road transport policies. While not directly involved in policy making, State Transport Undertakings are important actors in providing road mobility services for passengers within and between states (e.g., operators of transit buses).

[3] As of late 2022, the NCAP covered 131 so-called "non-attainment cities". These are cities whose air quality did not meet the national ambient air quality standards of 2011 to 2015 (CPCB, 2022).

Figure 2.1 Selected key institutions involved in road transport policy making



Notes: FAME = Faster Adoption and Manufacturing of Electric Vehicles scheme, PLI = Production-Linked Incentive scheme; NCAP = National Clean Air Program; NAPCC = National Action Plan on Climate Change; DISCOMs = Power distribution companies; CPCB = Central Pollution Control Board.

Historically, transport planning was conducted by sub-sector (NTDPC, 2014). Key documents relevant to urban road transport include the National Urban Transport Policy, first launched in 2006 and updated in 2014, and the National Transit Oriented Development Policy of 2017. The Automotive Mission Plan 2006-2016, primarily aimed at strengthening India's automotive industry, also included guidance on environmental dimensions (e.g., future directions for emission standards) and announced support for R&D in fuel-efficient and lower-emission vehicles (MHI, 2006). The revised draft plan to 2026 was prepared in 2016

(MHI, 2016), along with another draft policy called the National Auto Policy 2018, which calls for the adoption of a long-term roadmap for the sector that would, for example, set a pathway for future emissions standards in line with international developments, roll out corporate average fuel economy standards, and revise taxation to better account for the sector's environmental footprint (MHI, 2018). However, both documents are yet to be adopted. Once the policies therein are adopted, sufficient financial resources and institutional co-ordination and capacity will also be required to ensure that these objectives are realised and translated into better environmental outcomes.

In addition to these high-level strategies, in recent years the government has introduced several measures aimed at reducing the environmental footprint of road transport. As one of the missions adopted under the 2008 NAPCC, the National Mission on Sustainable Habitat (adopted in 2010 and revised in 2021) aims at developing comprehensive mobility plans that enable cities to undertake long-term, cost-effective and energy efficient transport planning (MoHUA, 2019a). In addition, the National Smart Cities Mission, launched in 2015, set in motion a set of actions to promote sustainable urban development, including efficient urban mobility and public transport (MoHUA, 2021). The National Mission on Transformative Mobility and Battery Storage, launched in 2019, provides a more focused approach towards integrated and electric mobility (NITI Aayog, 2022a). Various other initiatives and programmes were launched to promote efficient and cleaner road transport, many of which are described below.

Policies to promote electric vehicles

Road transport electrification is regarded as a key technology pathway for India to reduce CO_2 emissions and improve air quality while fostering economic growth and global competitiveness. India aspires to become a global leader in new mobility solutions and battery manufacturing (NITI Aayog and RMI, 2019).

India launched the National Mission for Electric Mobility in 2011. This plan was followed in 2013 by the National Electric Mobility Mission Plan (NEMMP) 2020 as the framework policy to promote the manufacturing and adoption of electric vehicles (EVs) (MHI, 2012). The plan set in motion a number of initiatives to stimulate the deployment of EVs along four priority areas: demand incentives, EV manufacturing, charging infrastructure development and R&D. The NEMMP had an ambitious vision for an EV penetration of 14%-16% of vehicle sales by 2020, and of 6-7 million sales by the year 2020. This target was not met, with less than half a million EVs being sold between 2013 and 2020 (MoRTH, 2022b).

The 2019 National Mission on Transformative Mobility and Battery Storage provided new impetus to the electrification of mobility in India, including programmes aimed at strengthening the manufacture of EVs, EV components and batteries in the country (NITI Aayog, 2022a). In addition, India signed the EV30@30 campaign of the Electric Vehicle Initiatives of the Clean Energy Ministerial (CEM, 2022), which sets the aspiration to reach a 30% sales share for EVs by 2030. India's EV market remains small but is growing steadily (Box 2.1). In addition to barriers around costs, charging infrastructure and range anxiety, EV uptake has also been held back by safety concerns following incidents of electric two-wheelers catching fire (The Economic Times, 2022c).

Box 2.1 Recent trends in EV sales

In the first half of the 2010s, EV sales remained below 10 000 vehicles per year, but started to gradually increase thereafter. The outbreak of the Covid-19 pandemic depressed sales of both EVs and conventional vehicles, but EV sales began to pick up again in mid-2021 and have been increasing exponentially since then. While the first half of 2021 registered less than 100 000 EV sales, this number increased to 230 000 in the second half of 2021, and exceeded 1 million units in 2022.

In 2021, 1.7% of new vehicle sales were EVs. This rose to 4.7% in 2022. However, the share varies considerably across vehicle categories: While more than 50% of three-wheeler registrations in 2022 were electric (as of early December), only 4% of two-wheelers and under 1% of cars and light commercial vehicles were electric. By the end of 2022, the EV fleet reached about 2 million vehicles, consisting largely of two- and three-wheelers. The electric car stock reached about 50 000. Nearly all sales were battery EVs.

Sources: MoRTH, GoI (2022b).

National policy instruments on the demand side

India's flagship programme to promote EVs is the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme, first adopted in 2015 under the NEMMP 2020. FAME is a demand-incentive programme aimed at reducing the upfront purchase price of hybrid and electric vehicles to stimulate early adoption and market creation. Phase I of the scheme (2015-2019) subsidised electric two- and three-wheelers, hybrid and electric cars, and electric buses with a budget outlay of INR 895 crore (USD 120 million).[4] It promoted some 280 000

[4] This report uses an exchange rate of 74.30 Indian Rupees Dirham (INR) per US Dollar (USD), based on the OECD National Accounts Statistics database (2021 end of period value) (OECD, 2022).

hybrid and EV sales, leading to an estimated 50 million litres of saved fuel and prevented 130 000 t CO_2, according to official statistics (MHI, 2022a).

The scaled-up FAME II was approved with a budget of over INR 10 000 crore (USD 1.3 billion), a more than tenfold increase from Phase I, from April 2019 to run for a period of three years (later extended to May 2024). About 90% of the budget targets EV purchase incentives, giving priority to public and shared transport, while 10% targets the deployment of charging infrastructure. FAME II aims to subsidise up to one million electric two-wheelers, 500 000 three-wheelers, 55 000 hybrid and electric passenger cars and 7 000 buses. In 2021, the government increased the subsidy for electric two-wheelers by 50% (from INR 10 000 to INR 15 000 per kWh) and relaxed the subsidy cap (from 20% to 40% of the sales price), which helped accelerate uptake. As of December 2022, FAME II had disbursed about one-third of its allocated budget (MHI, 2022b).

In addition to FAME, the government provides several other financial and non-financial incentives to stimulate EV uptake. Financial incentives include a reduced Goods and Services Tax (GST) on the purchase of an EV, EV chargers and charging stations (see details below). There is also an income tax exemption of up to INR 1.5 lakh (USD 2 020) per year on the interest paid on loans taken for the purchase of electric two- and four-wheeler vehicles. Non-fiscal incentives include an exemption from permit requirements for EVs in commercial applications, and the issuing of driving licences for 16- to 18-year-olds to drive gearless electric two-wheelers (up to 4 kWh battery size). In addition, the MoP launched the Go Electric Campaign in 2021 to spread awareness about the benefits of e-mobility, EV charging and electric cooking (MoP, 2021). In 2022, NITI Aayog launched the e-AMRIT (Accelerated e-Mobility Revolution for India's Transportation) portal as a "one-stop site" for creating awareness and providing all the information related to electric mobility in India (NITI Aayog, 2022b). Several other important EV policies are being deployed at the state level (Box 2.2).

Box 2.2 State-level EV policies

Around 30 states have developed state-level EV policies which are either in draft or have been adopted. Common objectives for promoting EVs include improving air quality, mitigating climate change, reducing oil import dependence and developing the EV industry. Most policies prioritise two- and three-wheelers, public transportation and job creation, but differ in terms of target definition and support measures used, whether demand- or supply-side incentives. About 14 states have additional demand incentives in the form of subsidies, while the others provide relief from vehicle taxes. The Delhi State EV Policy is among the most advanced;

it sets clear goals for the period up to 2030, including mandates for EVs in fleets. Some cities including Mumbai and Pune in Maharashtra, or Amritsar in Punjab have created comprehensive mobility plans which explicitly include EVs within overall transport infrastructure planning. The role of sub-national public policy in India will be key in driving EV transitions.

Sources: Ramji and Kankaria (2022); WRI India (2021).

National policy instruments on the supply side

India offers supply-side incentives to manufacturers of EVs and EV components, as well as for advanced chemistry batteries for EVs by means of two Production-Linked Incentive (PLI) schemes, which are part of a major government programme aimed at boosting India's manufacturing competitiveness in different sectors. With a budget outlay of INR 18 100 crore (USD 2.4 billion), the National Programme on Advanced Chemistry Cell Battery Storage aims to achieve a battery manufacturing capacity of 50 GWh (MHI, 2021a). In mid-2022, the government awarded funding to three companies under the scheme, with manufacturing expected to begin in 2024 (MHI, 2021b). The funding will be provided based on the sales of batteries manufactured in India and disbursed over five years. Beneficiaries must meet a domestic value added of at least 25% in year one; this requirement increases to 60% in year five.

The Automobile and Auto Component PLI scheme (MHI, 2021c) comprises two parts: the Champion OEM (Original Equipment Manufacturer) incentive scheme, which grants incentives for sales of advanced automotive technology vehicles (battery electric and hydrogen fuel cell vehicles), and the Component Champion scheme, which provides incentives for sales of certain components for both internal combustion engine (ICE) and EVs (although the incentive factor for ICE vehicle components declines over time). The budgetary outlay is INR 25 938 crore (USD 3.5 billion) over five years. A total of 95 applicants had been approved under this scheme. In both schemes, the minimum domestic value-added requirement is 50% (MHI, 2021b).

In parallel, the government mandated Energy Efficiency Services Limited (EESL), India's largest energy services company, to make bulk procurements of EVs to aggregate demand and achieve economies of scale. For example, Convergence Energy Services Limited (CESL), a subsidiary of EESL, successfully tendered for 5 450 electric buses in April 2022, in the largest such tender globally. The tender has helped discover significantly lower prices for operations of electric buses in public transport (MoP, 2022a). Based on this outcome, NITI Aayog and MoRTH requested CESL to deploy 50 000 electric buses.

National policies to promote charging infrastructure

The development of charging infrastructure is a key enabler of EV adoption (IEA, 2022a). The IEA's Global EV Outlook 2022 found that on average globally, 10 electric light-duty vehicles (LDVs) are served per public charger. However, this number varies widely, from 14 vehicles in the EU to 18 in the US and 32 in India. While the suitable number of chargers per EV depends on a number of factors (including mobility habits, fleets, population density, housing stock), the relatively high number of EVs served per public charger showcases the importance of continued investment in public charging infrastructure in India, especially as EV sales are growing. In Indian cities, most cars do not have dedicated parking spots, making public charging stations all the more important (IEA, 2022b).

The FAME II scheme is by far the largest subsidy package on charging infrastructure, allocating INR 1 000 crore (USD 135 million). While subsidies for up to 520 charging stations were approved under FAME I, nearly 4 450 charging stations were approved under FAME II across 68 cities, 9 expressways and 16 highways. The subsidies are distributed to cities that apply for these incentives with the MHI. By July 2022, 532 charging stations had been installed under FAME I and II (MHI, 2022b).

The government has also passed several regulatory changes to promote the installation of charging infrastructure, including the MoP's 2022 Guidelines and Standards for Charging Infrastructure for Electric Vehicles, which among other things eased provisions for EV owners to charge at home/office using existing electricity connections, and provided guidance on providing affordable tariffs (which are set by the states) and timelines for connectivity of charging stations to the grid. The regulations also re-define EV charging as a service (while it was previously defined as the sale of electricity), thus removing any licensing requirements for setting up and operating EV charging stations (MoP, 2022b). In 2019 the Ministry of Housing and Urban Affairs also amended the Model Building Bye-Laws for EV Charging Infrastructure to promote charging stations in residential and commercial properties (MoHUA, 2019b).

India's Union Budget announcement for 2022-2023 included provisions for a battery swapping policy that aims to provide "batteries or energy as a service" (MoF, 2022). Battery swapping provides an alternative charging solution, involving the removal of the discharged battery from the vehicle and replacing it with a fully charged one, at a designated swapping station. In April 2022, the government released a draft proposal of the policy which is to be rolled out in phases, focussing initially on metropolitan cities with a population larger than four million (NITI Aayog, 2022c).

Policies to promote fuel efficiency

Fuel efficiency improvements directly influence the amount of fuel consumed by vehicles, and therefore help reduce GHG and air pollutant emissions, save consumers money and support overall energy security by reducing oil imports. These multiple benefits are why fuel economy improvements are a cornerstone of road transport policy worldwide. Furthermore, stringent and continuous improvements in fuel economy standards can encourage automotive manufacturers to pivot from efficient ICE vehicles to EVs and other low-emission vehicles. India's LDVs are fuel efficient by international standards, but improvements have stalled in recent years (Box 2.3).

Fuel economy standards

India's current fuel economy regulations cover passenger cars, medium-sized trucks (MFTs) (3.5 to 12 t) and heavy freight trucks (HFTs) (above 12 t). The regulations were developed by the BEE based on the Energy Conservation Act, 2001.[5] The government is currently reviewing future pathways for fuel economy regulations across vehicle categories.

India's fuel economy regulations for passenger cars were adopted in 2015 as fleet requirements for manufacturers (also known as the Corporate Average Fuel Economy, or CAFE standards) (MoP, 2015). The regulation was implemented in a two-phased approach: In 2017 (Phase I), the vehicle fleet was to meet the target of 130 g CO_2/km; while for Phase II (which took effect in April 2022) the target is 113 g CO_2/km. The CAFE standards in India are first measured in terms of litre per 100 km, and then converted to equivalent g CO_2/km. This conversion also accounts for vehicle weight and provides some correction for fuel consumption requirements for heavier vehicles. Further, to reduce compliance costs and promote technological innovation, India introduced flexibility mechanisms, providing credits for electric and hybrid vehicles, as well as selected technologies (see Chapter 4).

The industry overachieved the targets by 6.6 g CO_2/km and 7.9 g CO_2/km in 2017 and 2018, respectively (CSE, 2021). More recent analysis shows that with the flexibility mechanisms provided in the CAFE regulations, there had not been any significant reductions in the average fleet emissions between 2018 and 2021 (ICCT, 2021a). Even so, manufacturers are expected to meet the 2022 Phase II standards through stronger use of flexibility mechanisms. To achieve real reductions in vehicle fleet CO_2 emissions, the stringency of fuel economy regulations will need to increase (see Chapter 4).

[5] The standards are also notified under the Central Motor Vehicles Act, 1988 and its Rules by the MoRTH for implementation.

Fuel economy regulations for heavy trucks (gross vehicle weight [GVW] of above 12 t) were defined in 2017 and for medium-sized trucks (3.5-12 t) in 2019 (BEE, 2022a). Unlike those for passenger cars, these regulations were adopted as per-vehicle standards, under which every vehicle model is tested for compliance before receiving a manufacturing approval certification. Vehicles are expected to meet fuel consumption targets (in litres/100km), based on the vehicle weight and axle configuration, as per a constant speed test cycle. Standards for heavy trucks were set to be implemented in a two-phase approach similar to that for passenger cars. Enforcement of the proposed standards had been put on hold (CSE, 2021) but recently the MoRTH re-notified Phase I standards and which were to come into force on 1 April 2023 (MoRTH, 2022c).

Box 2.3 Recent trends in fuel economy

The average rated fuel economy of India's LDV fleet has improved from 6.9 litres of gasoline equivalent (lge) per 100 km in 2005 to 5.7 lge/100 km in 2019, around 20% below the global average in 2019. This is firstly because India's LDVs have tended to be relatively small and light, with an average kerb weight of around 1.1 t for new cars sold in the 2010s, as favourable taxation and relatively high fuel prices pushed demand for small and energy efficient vehicles. Secondly, for most of the 2010s, more than 40% of India's car sales were diesel-fuelled ICEs, which are more fuel efficient than gasoline powertrains. However, the share of diesel cars has declined in recent years, to reach 18% in 2022.

As the average size and power of vehicles did not change much, despite low technology investments, fuel economy improved. In the United States and China, for example, technical improvements made between 2010 and 2019 were significantly larger than in India, but nearly 40% of these improvements were nullified due to the shift towards heavier and more powerful vehicles. In India, 17% of technical efficiency improvements were nullified by increasing vehicles' attributes in the same period. However, India is now experiencing a shift towards more fuel-intensive vehicles with the rising popularity of SUVs (sales reached 31% in 2019 compared to 17% in 2005) and a declining share of diesel powertrains.

Analysis and comparison of the fuel economy of India's truck fleet is complicated by differences in vehicle and engine sizes, load profiles and trip lengths. According to IEA estimates, the average fuel economy of freight trucks in India stood at about 25 litres of diesel equivalent (lde) per 100 km for MFTs and 45 lde/100 km for HFTs in 2017. In comparison, the average fuel economy for MFTs was about 23 lde/100km in the EU and China, while for HFTs it was around 35 and 39 lde/100 km in the EU and China, respectively.

Sources: IEA (2021b), IEA (2021c), IEA (2017), MoRTH, GoI (2022b).

Policies to reduce air pollutant emissions

Emissions standards

In 2000, India introduced the Bharat Stage (BS) Emission Standards modelled on the EU norms. The BS-IV standards were implemented in 2017, and in April 2020 – establishing a precedent of global relevance – India successfully leapfrogged to the implementation of BS-VI. These largely parallel Euro-6/VI norms. The BS standards regulate tailpipe emissions including PM, SO_x and NO_X as well as carbon monoxide, hydrocarbons and methane. Developed for all vehicle categories, they are applied to vehicles manufactured after April 2020 (ICCT, 2016).

Transitioning from BS-IV to BS-VI standards required significant changes for vehicle manufacturers. For example, BS-VI requires diesel vehicles to contain advanced emission control technologies (after-treatment solutions for NO_X and PM) that increase upfront costs. As a result, the market share of diesel-powered passenger cars dropped from 30% in 2019 to 18% in 2020. There has also been a shift from diesel to gasoline engine vehicles in the light commercial vehicle (LCV) fleet (ICCT, 2021a, 2021b). Manufacturers of two-wheelers were for the first time required to introduce a fuel injection system to meet the BS-VI standards.

Vehicle scrappage policy

India's new vehicle scrappage policy took effect (MoRTH, 2022d) on 1 April 2022. The objective of the policy is to phase out old passenger and commercial vehicles and thereby reduce urban air pollution, increase passenger and road safety, and stimulate automotive sales (IBEF, 2021). The policy brings about two main changes to India's automotive sector. First, it establishes norms that regulate vehicle phase-out at the national level with the potential to improve knowledge about vehicle retirements and to harmonise registration rules across states. Second, the policy has the potential to accelerate the formalisation of vehicle scrappage and recycling, which is today a largely unregulated, informal sector (ETAuto, 2021, The Economic Times, 2020).

The policy requires passenger vehicles older than 20 years and commercial vehicles older than 15 years to pass a "fitness and emissions test" to keep their registration. Vehicles failing the test are defined as end-of-life vehicles, lose their registration certificate and are recommended to be scrapped. The policy also introduces incentives to scrap old vehicles, including discounts on the purchase of new vehicles against a scrappage certificate. According to the MoRTH, some 12 million passenger and commercial vehicles are currently without a valid fitness test or registration, and it is not clear how many of these were scrapped, and how many are still running. To strengthen the scrappage policy, MoRTH announced that government-owned vehicles older than 15 years will lose their registration certificate and be scrapped from April 2023 onwards (MoRTH, 2022e).

A prerequisite for successful implementation of this policy is the availability of testing centres and scrappage yard capacity (Al Jazeera, 2022). MoRTH currently envisages the construction of around 400 automated testing centres – which could guarantee objective testing and limit fraud – and the establishment of up to 75 scrappage yards in the next few years. Financial incentives to scrap old vehicles, as distinct from repurchasing a new vehicle, could further encourage scrappage. Possibilities to further develop this policy and measures to promote vehicle scrapping and their replacement with low-emissions options are discussed in Chapter 4.

Policies to promote alternative fuels

The 2018 National Policy on Biofuels aims to increase the penetration of biofuels in the energy and transportation sector. It proposed an indicative target of a 20% blending of ethanol in gasoline and a 5% blending of biodiesel in diesel by 2030. The 2025 Ethanol Roadmap, released in 2021, advanced the 20% national ethanol blending target (E20) by five years to 2025, and placed a renewed focus on food-based feedstocks such as maize, rice or sugarcane for ethanol production. This departs from the Ethanol Blended Programme laid out under the 2018 National Policy on Biofuels, which prioritised second-generation feedstock, in an attempt to reduce supply chain constraints (MoPNG, 2018, NITI Aayog and MoPNG, 2021).

From 2017 to 2021, ethanol blending in gasoline increased from 2% to 8% in India, whereas biodiesel blending accounts for less than 0.1% (IEA, 2021d; USDA, 2021). Despite a range of incentives being provided, achieving the 20% blending target will be challenging given the uncertainty around vehicle compatibility with fuel blends above E10 as well as concerns around feedstock availability and the implications for food security, trade balances and environmental sustainability (IEA, 2021d; ICCT, 2021c).

In August 2021, India announced a National Hydrogen Mission tasked with meeting mitigation goals as well as making India an export hub for "green" hydrogen and "green" ammonia. A Green Hydrogen and Green Ammonia Policy was adopted in February 2022 (MoP, 2022c). The policy aims to scale up green hydrogen production to 5 Mt by 2030 and to increase its use in different sectors, including transport.

India aims to increase the share of natural gas in the total energy mix to 15% by 2030 (from about 6% today) and to implement more policies to promote natural gas consumption in different sectors (MoPNG, 2022). In 2014, the government permitted greater allocation of natural gas to Piped Natural Gas (PNG) and

Compressed Natural Gas (CNG) to promote natural gas use for cooking and in transport vehicles. This policy has reduced CNG prices to levels below those of gasoline and diesel. However, CNG consumption in transport is held back by limited supply and distribution infrastructure.

Vehicle and fuel taxation

Road transport-related taxes and fees can be categorised into three components: those levied when the vehicle is purchased (GST, purchase tax and registration fees), those levied on fuels (excise duty, VAT and any other tax/cess on diesel, gasoline, CNG and electricity), and road pricing (tolls on city roads and highways).

All vehicle purchases are subject to the GST, which is uniform across India. It is generally levied at a rate of 28%, though a reduced rate of 18% applies to small passenger cars. For EVs, a 5% GST applies. In addition to the GST, a "compensation cess" is applied on ICE vehicles, acting as a shadow environmental compensation charge. Like the GST, the compensation cess for passenger vehicles is differentiated by vehicle length and engine size. This contrasts with vehicle tax designs in other countries, where vehicle taxation is often based on weight or CO_2 emissions to incentivise the purchase of vehicles with lower environmental footprints. The compensation cess, however, is higher for diesel-fuelled cars, to account for their higher emissions or air pollutants relative to those of gasoline-fuelled cars. Table 2.1 summarises the GST, compensation cess and resulting total tax rate for different vehicle categories.

Buyers of vehicles for private use also pay a one-off registration fee and road tax at the time of vehicle registration. Taxes are levied annually on commercial vehicles such as taxis, buses, freight trucks and three-wheelers. The rates of the registration fee and road tax can vary considerably across states (the one-off road tax, for example, ranges from 5% to 13% of the cost of the vehicle). In August 2021, the government declared that EVs will be exempt from fees for issuing or renewing registration certificates, but not all states have implemented this measure.

Table 2.1 GST and compensation cess rates in India

Vehicle categories	GST	Compensation cess	Total purchase tax rate
Small passenger vehicles using gasoline, CNG or LPG (<4m length and <1 200 cc engine)	18%	1%	19%
Small passenger vehicles using diesel (<4m length and <1 500 cc engine)	18%	3%	21%
Mid-size passenger vehicles (>4m length and <1 501 cc engine)	28%	17%	45%

Vehicle categories	GST	Compensation cess	Total purchase tax rate
Large passenger vehicles (>4m length and >1 500 cc engine)	28%	20%	48%
SUVs (>4m length, >1500cc engine and >169mm ground clearance)	28%	22%	50%
Hybrid vehicles (except small)	28%	15%	43%
Two-wheelers (between 150 cc and 180 cc)	18%	3%	31%
10-13 seater public transport vehicles	28%	15%	43%
Electric vehicles	5%	-	5%

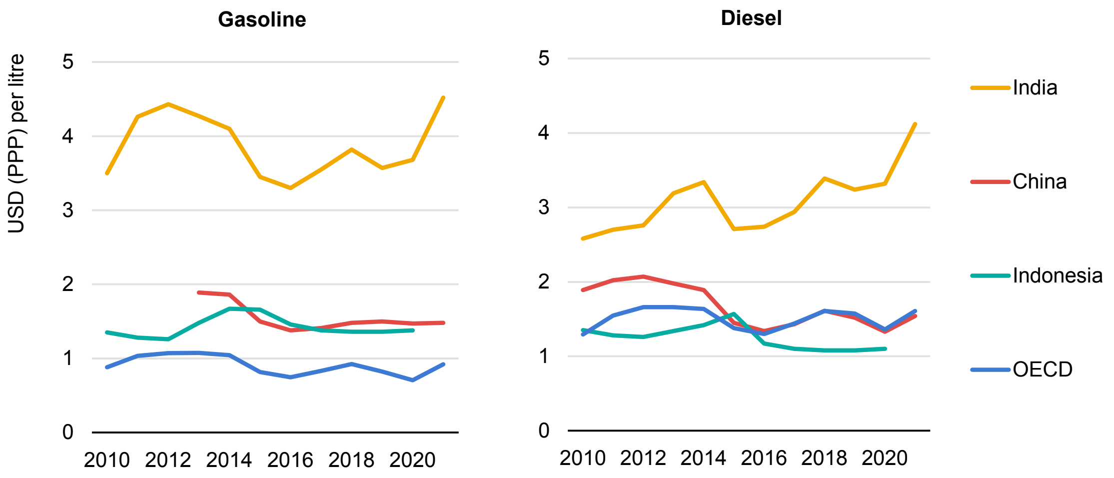
Notes: GST stands for Goods and Services Tax. For categories not included in the table, the total purchase tax rate is equal to the standard GST, at 28%.
Source: IEA analysis based on Cleartax.in (2022).

Fuel taxation for gasoline and diesel includes three main components: a fuel excise duty, a sales tax (or VAT) and any additional surcharges or cess. The fuel excise duty, levied by the central government, is based on volume and is uniform across the country, at INR 19.9 (USD 0.27) per litre gasoline and INR 15.80 (USD 0.21) per litre diesel in mid-2022. The VAT is levied by the states and its rate varies between 3% and 40% of the sales price depending on the state.[6] Most states apply higher VAT rates for gasoline than for diesel to keep fuel prices lower for the trucking and logistics sector. Both the excise duty and the VAT are often modified by central and state governments to accommodate fluctuations in international crude oil prices. In addition to the VAT, states also levy different surcharges or additional cess on gasoline and diesel to finance infrastructure investment, address pollution, etc. These are calculated either as a percentage of the VAT or as a fixed amount.

On average, the excise duty contributes about one-third of the retail fuel price for both diesel and gasoline, while the VAT contributes about 15-20%; state surcharges and cess generally contribute a small share. Depending on the state, taxes can make up for more than half of the retail price, which is high by international comparison and partly explains why fuel prices in India are comparatively high when expressed in purchasing power parity terms (Figure 2.2). As discussed in Chapter 4, fuel taxes and duties yield considerable revenue to both the central and state governments.

[6] The VAT for gasoline, for example, varies between 1% (Andaman and Nicobar Islands) and 35% (Telangana) of the sales price, while for diesel it varies between 1% (Andaman and Nicobar Islands) and 27% (Telangana).

Figure 2.2 Gasoline and diesel prices in India and selected jurisdictions, 2010-2021



Note: PPP= purchasing power parity.

Electricity tariffs for EV public charging vary considerably across states and consumer categories, reflecting differences in base tariffs, taxes and charges. Several states levy additional charges; for example, Delhi levies a 3.8% pension trust surcharge on all electricity end consumers while, until 2020, Karnataka charged industrial and commercial consumers a "green energy cess" per unit of electricity consumed. Data on the end-user charges applying in each consumer category is not readily available. The MoP's 2022 Guidelines and Standards for Charging Infrastructure for Electric Vehicles state that until March 2025 electricity tariffs should be a single part tariff (meaning that tariffs are not differentiated with the amount of electricity consumed) and not exceed the average cost of supply. The guidelines note that charging is a service; therefore, state governments can fix a ceiling service charge for electricity. Residential tariff rates will be applied for domestic charging (MoP, 2022d).

In terms of road pricing, tolls are collected at national and state highways, as well as city roads, depending on the infrastructure being created and maintained. Toll roads are typically constructed in a public-private partnership or a build-operate-transfer model, where tolls are a mechanism for realising returns on investment by the private operator.

Chapter 3. Future pathways

This chapter lays out two different pathways for India's road transport sector. It compares how India's current policy framework will shape the road transport sector's vehicle stock, energy demand and emissions with another pathway that reflects a more ambitious set of policies up to 2050, taking into account India's long-term climate ambition to achieve net zero carbon emissions by 2070. The chapter aims to highlight the road transport categories and technologies for which policy gains are highest in terms of energy savings and avoided emissions.

Modelling framework and scenarios

This chapter's analysis is based on two scenarios developed for the IEA World Energy Outlook (WEO). As the IEA does not hold a single view about the long-term future of the global energy system, these scenarios are not predictions. Instead, they lay out different possible versions of the future and the levers that bring them about.

The first scenario explored is the Stated Policies Scenario (STEPS). This is the IEA's main benchmark scenario. It reflects current policy settings and provides a benchmark to analyse the potential achievements and limitations of a country's existing energy and climate policies. The Announced Pledges Scenario (APS) builds upon the STEPS and assumes that all energy and climate commitments made by governments, including long-term net zero goals, will be met, fully and on time. At a global level, the APS aims to show how close all countries' combined climate ambitions will come to meeting the global temperature objectives of the Paris Agreement, thus highlighting the "ambition gap" (IEA, 2022c).

Scenario projections for energy consumption and CO_2 emissions stem from the IEA's WEO 2022 (IEA, 2022d), which used the IEA's Global Energy and Climate (GEC) Model (IEA, 2022c). The air pollutant emissions and related health impacts resulting from energy use are provided by the International Institute of Applied Systems Analysis (IIASA). For this purpose, the IEA's GEC Model and IIASA's Greenhouse Gas and 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 (IIASA, 2022).

Table 3.1 Overview of selected policies and relevant scenario assumptions in the STEPS and APS

	STEPS	APS
Definition	Reference scenario, reflects India's current policy framework, including key policies implemented or announced by the Government of India.	Builds upon STEPS, assumes that all climate commitments made by the Government of India, including its NDCs and long-term climate targets, will be met in full and on time.
Selected policy assumptions for India		
Cross-cutting energy and climate policies	• Energy-related components of the "Self-Reliant India Scheme". • Achievement of 450 GW renewables capacity and 50% non-fossil fuel-based energy sources of total installed capacity by 2030. • Energy Conservation Act amendment, 2022.	In addition to assumptions in the STEPS: • Follows a trajectory to net zero emissions by 2070. • Achievement of 45% reduction in the economy's emissions intensity by 2030 from 2005 levels, as stipulated in India's Updated NDC. • Achievement of 500 GW in non-fossil energy capacity by 2030 and reduction of emissions by 1 Gt CO_2 by 2030, as announced by the Prime Minister at COP26 in 2021.
Transport policies	• Implementation of FAME II; selected EV policies at state level. • Partial implementation of amended biofuel policy, 2022. • Fuel economy standards for cars at 113 g CO_2/km; fuel economy targets for HDVs. • Bharat Stage VI emissions standards for LDVs and HDVs. • Urban and public transit investments.	In addition to assumptions in the STEPS: • Extension of FAME II to support sales of 500 000 electric three-wheelers and 1 million electric two-wheelers. • National railway target of net zero emissions by 2030.
Exogenous assumptions		
Capital costs for BEVs (Global average)	2021: USD 21 322 2030: USD 15 772	2021: USD 21 322 2030: USD 15 265
Demand management	Compared to the STEPS, the APS assumes an enhanced uptake of public transport.	
Average annual GDP growth (India)	2021-30: 7.2% 2021-50: 5.2%	
Average annual population growth (India)	2021-30: 0.8% 2021-50: 0.6%	

Notes: LDV stands for light-duty vehicle and includes passenger cars and light commercial vehicles, HDV stands for heavy-duty vehicle and includes freight trucks and buses. BEV stands for battery electric vehicle.
Source: IEA (2022d).

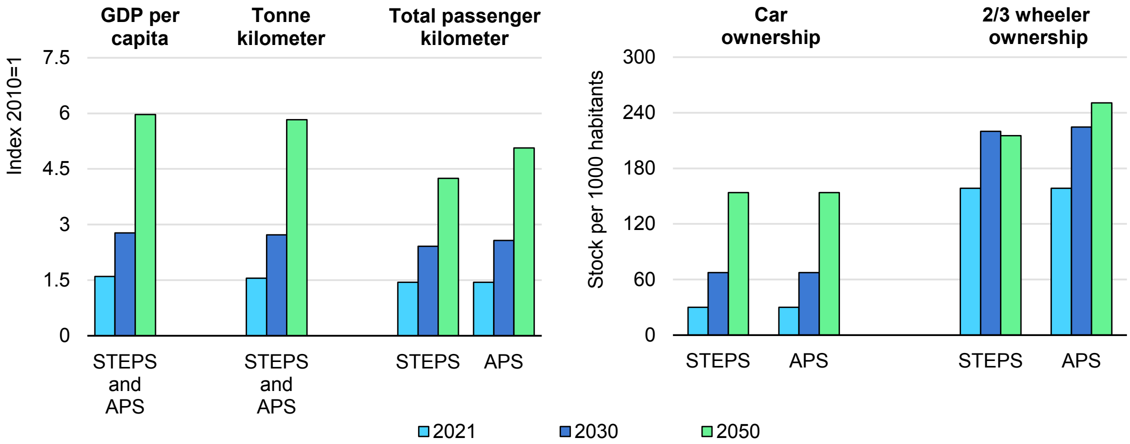
Assumptions relating to economic activity and population growth, two fundamental drivers of energy demand, are the same for both scenarios. GDP is projected to continue to grow strongly, at about 5% per year in real terms on average between 2021 and 2050, and GDP per capita at 4.7%. Continued population growth will soon make India the world's most populous country. By 2050, the population is expected to exceed 1.6 billion people (up from 1.4 billion in 2021). Combined with the twin forces of urbanisation and industrialisation, this increases total energy demand by more than 3% annually in the STEPS between 2021 and 2030 – the largest increase in energy demand in any country. Despite strong efforts to increase energy efficiency and the use of renewable energy sources, the sheer scale of India's development means that import bills for fossil fuels double over the next two decades in the STEPS, posing a potential risk for energy security (IEA, 2022d). Road transport contributes more than 15% to the overall growth in energy demand between 2021 and 2030.

Future pathways of India's road transport

Strong GDP and GDP per-capita growth as well as population growth and urbanisation continue to drive up the demand for transporting people and goods. Total road transport activity (measured in vkm) increases by more than 2.5 times by 2050 in both scenarios. Ownership of motorised vehicles continues to grow strongly, for two-wheelers and particularly for private cars (Figure 3.1). Private vehicles (passenger cars and two-wheelers[7]) continue to account for some 90% of total road transport activity, but the importance of these reverses: while two- and three-wheelers accounted for two-thirds of vkm in 2021, this share drops to about 40% by 2050, while that of passenger cars more than doubles to 50%. Total passenger mobility, measured in passenger-kilometres (pkm), is higher in the APS, reflecting a stronger uptake of public transport, in particular rail services. The transport of goods, measured in tonne-kilometres (tkm), almost quadruples between 2021 and 2050.

[7] The IEA WEO model regards two- and three-wheelers as one category. Two-wheelers are largely used for personal use, while three-wheelers can be used only for commercial purposes (passenger and cargo transport) in India. Two-wheelers account for a large majority of vehicles within this category. According to India's national vehicle registration database, two-wheelers accounted for 97% of registered two-and three-wheelers in 2021 (MoRTH, 2022a).

Figure 3.1 Key indicators for development of mobility and goods movement in India's road transport sector in the STEPS and APS, 2021, 2030 and 2050



Vehicle fleet development

In both scenarios, the number of vehicles on India's roads is projected to increase by about 60% over the next decade to more than 450 million in 2030. The fleet growth is primarily driven by a massive increase in passenger cars and two-wheelers, although the fleet of commercial vehicles also increases. The share of EVs in the fleet is projected to continuously increase, exceeding India's aspirational target of 30% EV sales by 2030, under current policies, largely due to rapid electrification of two- and three-wheelers. By 2050, this share is projected to reach nearly 70%. In the APS, EVs already account for nearly half of vehicle sales by 2030, and by 2050 nearly all new vehicles sold are electric. Reaching these higher sales shares in the APS will require that an additional 23 million EVs be sold between today and 2030.

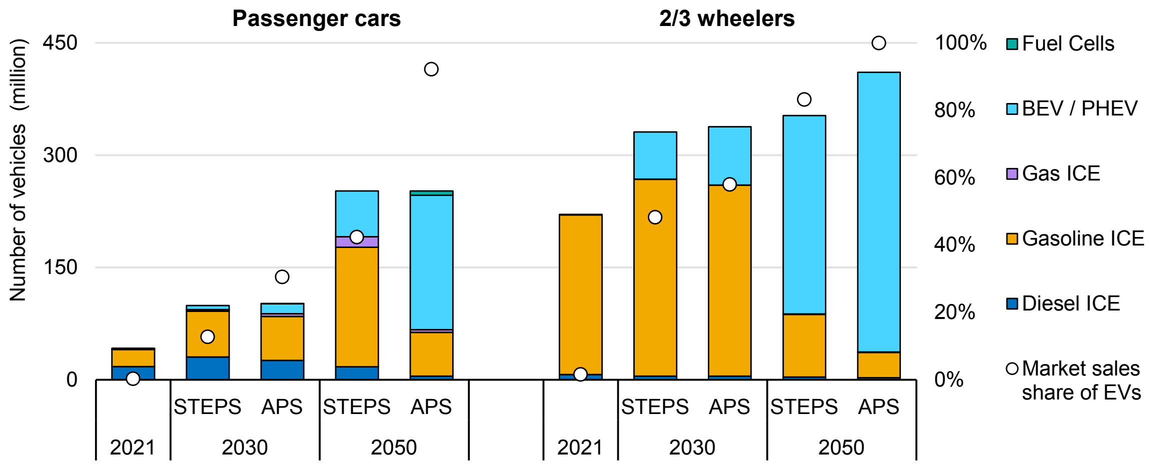
Passenger cars and two- and three-wheelers

In both scenarios, India's car ownership rate surges from 30 to about 150 cars per 1 000 inhabitants between 2021 and 2050 (Figure 3.1), increasing the passenger car fleet to more than 100 million in 2030 and 250 million by 2050. Such a rapid expansion, in combination with a strong urbanisation rate, will pose challenges for urban traffic management and a risk of worsened air pollution, depending on the technologies used by the new vehicles.

While currently almost exclusively consisting of ICE vehicles, India's private vehicle fleet is projected to gradually shift to electric powertrains in the future. In the STEPS, the uptake of electric cars is modest, with sales reaching 13% in 2030 and about 40% of total passenger sales by 2050. As a result, ICEs continue to make up three-quarters of the car fleet by 2050. In the APS, in contrast, electric cars reach a market sales share of 30% in 2030 and more than 90% by 2050. By 2050, EVs dominate the car fleet (about 70%) while most of the remaining vehicles are gasoline-fuelled ICEs (Figure 3.2).

Two- and three-wheelers are projected to be the frontrunners for electrification, as electric models in this category become cost competitive more rapidly (see Chapter 4) and users have fewer concerns around driving range and charging infrastructure. In the STEPS, sales of electric two- and three-wheelers make up half of the market by 2030 and more than 80% in 2050. In the APS, an 80% market share is already reached in the second half of the 2030s, while by 2050 all two- and three-wheelers sold are electric.

Figure 3.2 Passenger cars and two- and three-wheelers fleet by powertrain and EV sales shares in the STEPS and APS, 2021-2050



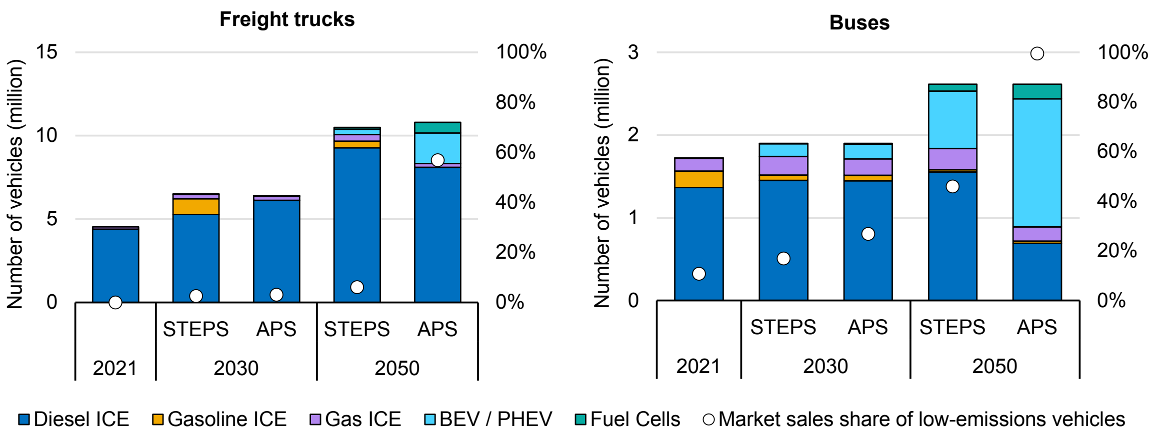
Notes: BEV stands for battery electric vehicle. PHEV stands for plug-in hybrid electric vehicle.

Heavy-duty vehicles

Heavy-duty vehicles (HDVs), including buses and medium and heavy freight trucks, currently make up less than 3% of India's vehicle fleet and in both scenarios the share is projected to remain stable going forward. These vehicles, however, account for half of both road transport energy consumption and CO_2 emissions. The deployment of low-emissions technology therefore plays a crucial role in reducing the negative environmental consequences of road transport expansion in India.

The fleet of freight trucks more than doubles by 2050 with freight activity (in tkm) increasing nearly six-fold in both scenarios. India's truck fleet today is split roughly evenly between medium and heavy freight trucks. By 2050, HFTs are projected to make up more than 70% of trucks in both scenarios, as improved road conditions in the future allow for the deployment of larger vehicles that may transport goods more efficiently. In 2021, freight trucks almost exclusively ran with diesel engines and this will not change substantially in the STEPS, with low-emissions trucks (electric and hydrogen models) still accounting for only 5% of sales by 2050. In the APS, by contrast, the share of low-emissions trucks reaches 5% in the early 2030s and approaches 50% by 2050. As a result, they make up almost one-quarter of the truck fleet in three decades (Figure 3.3). This implies, nonetheless, that in both scenarios diesel-powered trucks continue to dominate the truck fleet until 2050, highlighting the critical importance of fuel efficiency improvements in this vehicle category.

Figure 3.3 Heavy-duty vehicle fleet by powertrain in the STEPS and APS, and EV sales shares, 2021-2050



The number of buses on Indian streets continues to grow in both scenarios from 1.7 million in 2021 to 2.6 million in 2050. Today, some 80% of India's buses are diesel-fuelled ICEs, with most of the others running on gasoline and CNG. While in 2021 less than 0.2% of the bus fleet was electric, the strong push for electrification under the FAME scheme as projected in STEPS could bring the share of electric buses in the total fleet up to 8% in 2030 and to 25% in 2050. In the APS, electric buses could make up nearly 10% of the fleet in 2030 and nearly three-quarters of the fleet by 2050 (Figure 3.3). To achieve such a strong shift in the bus fleet, nearly 20 000 electric buses need to be deployed each year on average between 2021 and 2030 in the APS. Buses powered with fuel cells could be available from the mid-2020s and account for 7% of the stock in 2050 in the APS.

While both scenarios project the bus fleet to decarbonise almost solely through electrification, the STEPS further foresees a higher uptake of CNG buses compared to the APS. CNG buses have increased over the last decade, reflecting policy efforts to improve local air quality by replacing old, highly-polluting diesel buses. Delhi, for example, is home to one of the largest fleets of CNG-powered buses in the world (IEA, 2021e). Yet recent analysis has shown that CNG-powered vehicles emit a large number of particles, and calls for a careful assessment of the benefits these vehicles can bring in terms of better urban air quality (T&E, 2020).[8]

Final energy consumption

Energy consumption from road transport is projected to more than double up to 2050 in the STEPS, to 215 Mtoe. The increase is entirely driven by cars and trucks (Figure 3.4). In the APS, energy demand growth is reduced by 30%, and energy consumption reaches less than 145 Mtoe by 2050. Following the APS trajectory, India could therefore save 70 Mtoe in the year 2050 – nearly 80% of the sector's energy consumption today. The fuel savings are realised through considerable fuel economy enhancements, driven mainly by the switch to EVs, which are two to four times more energy efficient than comparable ICEs (IEA, 2022b).[9] Further, ICE vehicles become more efficient.

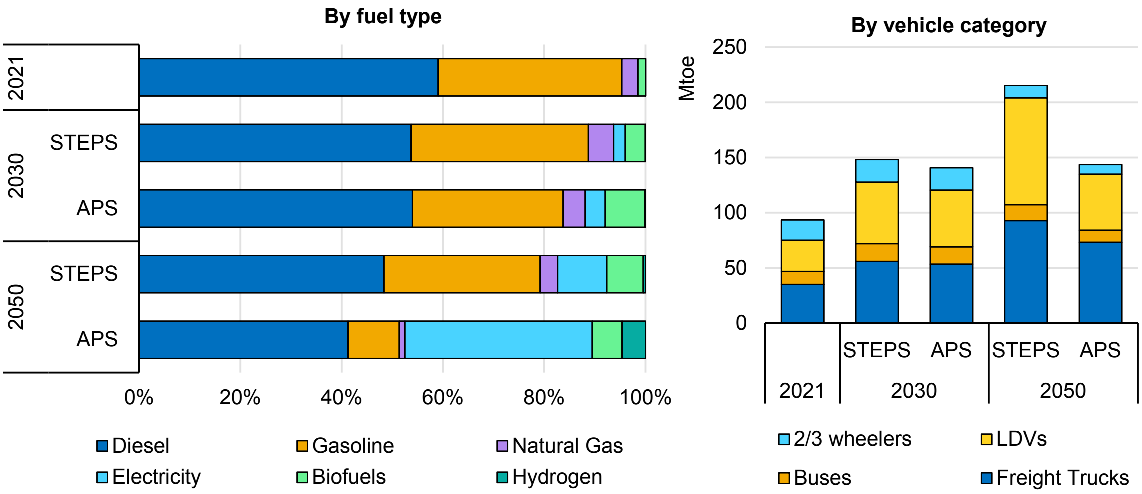
In the STEPS, gasoline and diesel continue to meet some 80% of the demand in 2050, while electricity contributes only around 10%, and biofuels and CNG make up the remainder. In the APS, by contrast, gasoline and diesel meet only half of road transport's energy requirements in 2050, and is used mostly by trucks and buses. Electricity meets nearly 40% of the sector's energy needs by mid-century (noting that the share of EVs in total vehicle activity would be considerably higher, given their higher efficiency in terms of energy consumption per kilometre travelled).

Biofuels are projected to increase faster in the APS to 2030, but not significantly thereafter. By 2050, biofuels meet 6-7% of energy supply for road transport in both scenarios (Figure 3.4). Natural gas consumption is set to increase in both scenarios up to 2030, after which it continues to grow in the STEPS, but declines in the APS. In the STEPS, both biofuels and natural gas are consumed primarily by passenger cars in 2050, whereas in the APS these fuels are used mainly for heavy trucks and buses, given that cars are expected to be largely electrified by then. Hydrogen starts to play a visible role in the 2040s in the APS and could satisfy 5% of the road transport sector's energy demand in 2050, six times as much as in the STEPS. Hydrogen in the APS is used for both passenger cars and heavy freight trucks.

[8] The latest data on particle pollution from CNG cars, vans, buses and trucks dispels the notion that these vehicles do not emit high levels of particles, including $PM_{2.5}$, especially in urban driving conditions. Further, CNG vehicles can emit large amounts of ammonia which contributes to secondary particle formation (T&E, 2020).

[9] EVs are more efficient than comparable ICE vehicles on an energy per km basis, because EVs convert over 77% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles convert only about 12-30% of the energy stored in gasoline to power at the wheels (United States, Department of Energy, 2022).

Figure 3.4 Fuel consumption in road transport in the STEPS and APS, 2021-2050



IEA. CC BY 4.0.

Passenger cars and two- and three-wheelers

While two- and three-wheelers are more energy efficient than larger and heavier vehicles, the sheer size of the two-wheeler fleet evinces its important role in the energy demand of road transport in India. In 2021, two- and three-wheelers accounted for one-fifth of the total amount of energy consumed in road transport and half of total gasoline consumption. Even though the fleet will continue to grow, the switch to more energy efficient EVs means that the fleet's energy needs peak before 2030 and fall below today's level by the mid-2030s in both scenarios (Figure 3.5). By 2050, energy demand in the APS is 25% lower than in the STEPS, despite a larger fleet and higher road activity, due to even more rapid electrification.

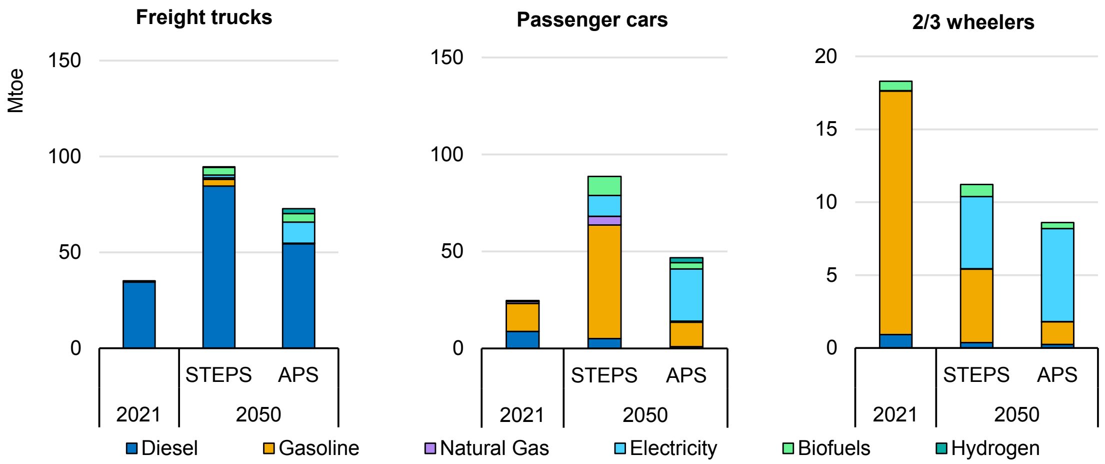
Passenger cars accounted for about a quarter of total energy consumption in road transport in 2021 and consumption is projected to nearly quadruple by 2050 in the STEPS, increasing its share to above 40% owing to to fleet growth and continued reliance on gasoline-fuelled ICE vehicles. In the APS, a fleet of the same size, but different composition with respect to fuels and powertrains could curb demand growth to a level 50% below the consumption projected in the STEPS. In contrast to the STEPS, electricity accounts for most of the energy consumption by 2050 (60%), while gasoline meets less than 30% (Figure 3.5).

Heavy-duty vehicles

HDVs accounted for half of the road transport sector's energy consumption in 2021, with freight trucks accounting for nearly 40% and buses for the remainder. In the STEPS, the energy consumption of trucks increases by 60% until 2030 and thereafter declines as fuel efficiency improvements outweigh the growing fleet. By

2050, trucks' fuel consumption is 2.5 times above 2021 levels and diesel account for more than 90% of trucks' fuel demand in 2050 (Figure 3.5). In the APS, trucks' energy consumption also increases until the 2030s, but it remains 20% below the STEPS in 2050, due to better fuel efficiency in ICEs and a higher share of low-emission vehicles.

Figure 3.5 Final energy consumption in road transport by vehicle category in the STEPS and APS, 2021 and 2050

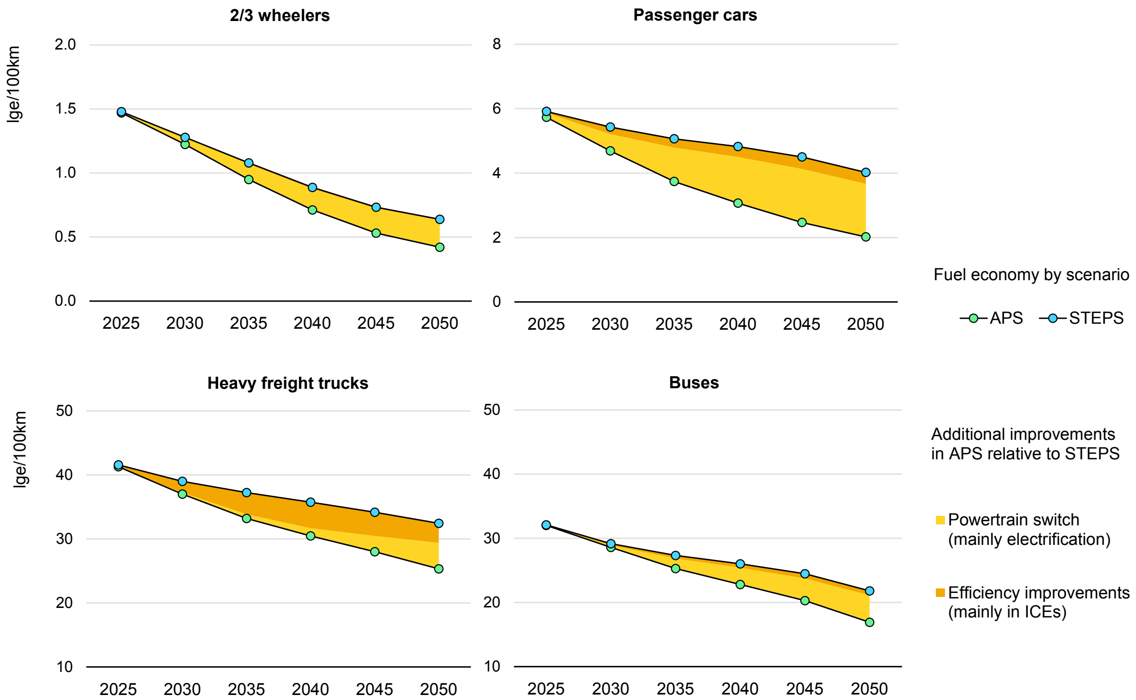


Fuel economy improvements in different vehicle categories

Fuel economy improvements can be achieved either through fuel economy enhancements within powertrain technologies (e.g. more fuel-efficient gasoline engines) or through higher shares of more fuel-efficient vehicle types, such as EVs, in the fleet. The potential contribution of each option varies across categories and develops over time, as shown in Figure 3.6. The fuel economy improvements of two- and three-wheelers show the smallest gap between the two IEA scenarios: Compared to 2021, fuel consumption per km drops by 60% in the STEPS and 75% in the APS, as electrification quickly becomes economically viable in both scenarios, and simply rolls out more rapidly in the APS. Among passenger cars, fuel economy improves by around 30% in the STEPS, and around 65% in the APS, mainly due to faster electrification.

The fuel efficiency of the heavy trucks fleet is projected to improve by nearly 25% up to 2050 in the STEPS, driven by fuel economy improvements in diesel powertrains. In the APS, diesel powertrains become even more efficient, and switching powertrain technologies to zero-emission technologies (i.e. electric or hydrogen-fuelled models) brings additional fuel efficiency enhancements, particularly after 2040. The fuel efficiency of the bus fleet is expected to improve by about 30% in the STEPS up to 2050, achieved through both technology switching and powertrain efficiency improvements. In the APS, an additional enhancement of 20% is realised through a stronger shift from diesel-fuelled buses to electric buses.

Figure 3.6 Drivers of additional fuel economy improvements in the APS relative to the STEPS, 2025-2050



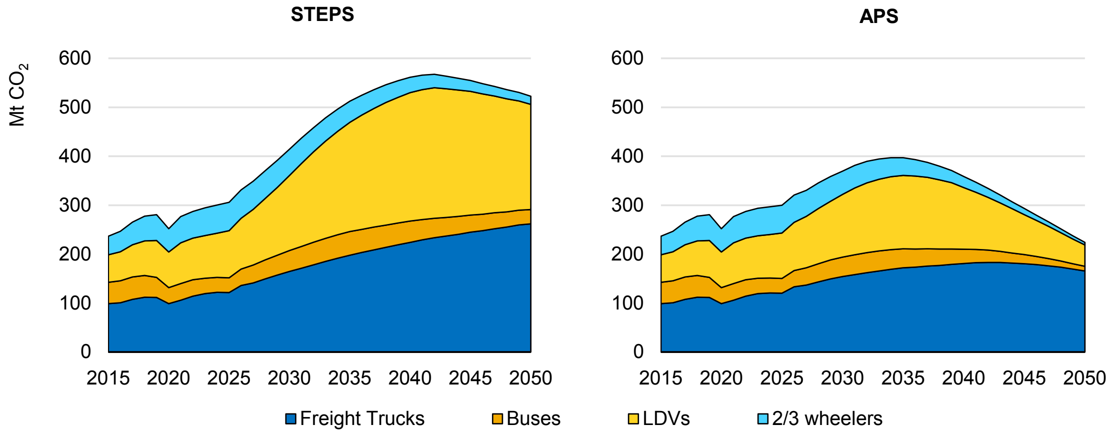
Notes: Fuel economy is measured in litres of gasoline equivalent per 100 km (lge/100km). Converting a fleet's fuel economy from lge/100km to g CO_2 per km requires additional assumptions relating to the accounting of test cycles, biofuel blending and fossil fuel type.

Environmental impacts

CO_2 emissions

At around 280 Mt CO_2, India's road transport accounted directly for 12% of India's total energy-related and more than a quarter of energy demand-related CO_2 emissions in 2021. However, as the road transport sector grows and the power sector rapidly decarbonises through large-scale renewables deployment, the share of road transport in total energy-related CO_2 emissions is set to increase to nearly one-fifth in the STEPS and a quarter in the APS by 2050. In absolute terms, road transport-related emissions in the STEPS double by 2040 to 560 Mt CO_2, and do not significantly decrease afterwards. The increase is driven by the expansion of the freight truck and passenger car fleet. In the APS, by contrast, emissions peak in the mid-2030s and substantially fall thereafter to below 230 Mt CO_2 by 2050, 60% below the STEPS level (Figure 3.7).

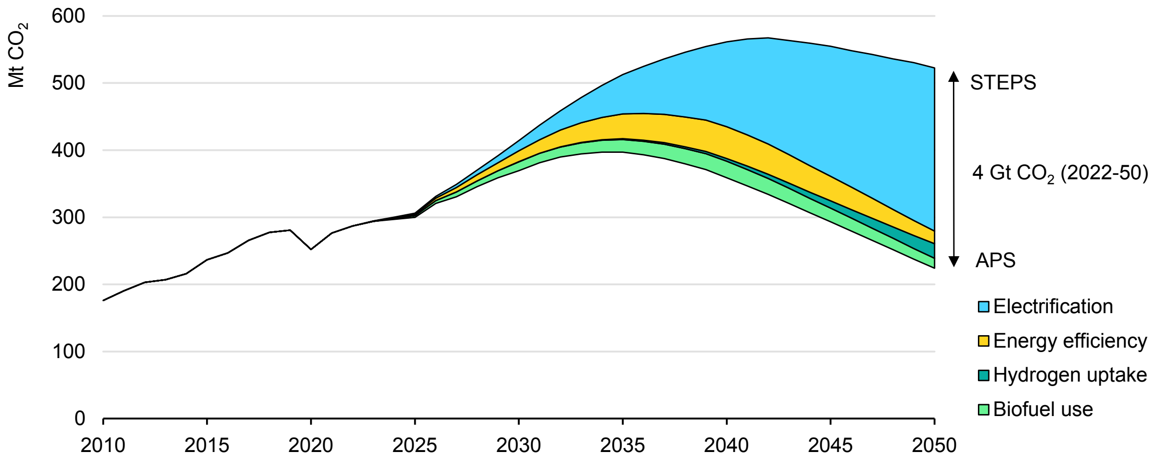
Figure 3.7 CO_2 emissions by vehicle category in the STEPS and APS, 2015-2050



Pursuing a more ambitious transition as laid out in the APS, the transport sector could emit 4 Gt CO_2 less than under current policies between 2022 and 2050. Up to 2030, stronger energy efficiency improvements (mainly in ICEs), an accelerated uptake of EVs and a higher use of biofuels each contribute about one-third to the additional reductions. From 2040 to 2050, however, faster electrification achieves nearly 75% of the additional abatement; hydrogen, mainly used in freight trucks, rapidly scales up and adds another 5%. The significant abatement potential of energy efficiency improvements would have been largely tapped by 2040 (Figure 3.8).

While EVs have no tailpipe CO_2 emissions, the electricity generated to power EVs causes emissions at the power plant level. India's current electricity generation mix is dominated by fossil fuels, primarily coal and thus indirectly contributes to CO_2 emissions in the road transport sector (see Box 3.1). The mitigation potential of road transport electrification is therefore closely linked to the pace of India's power sector decarbonisation.

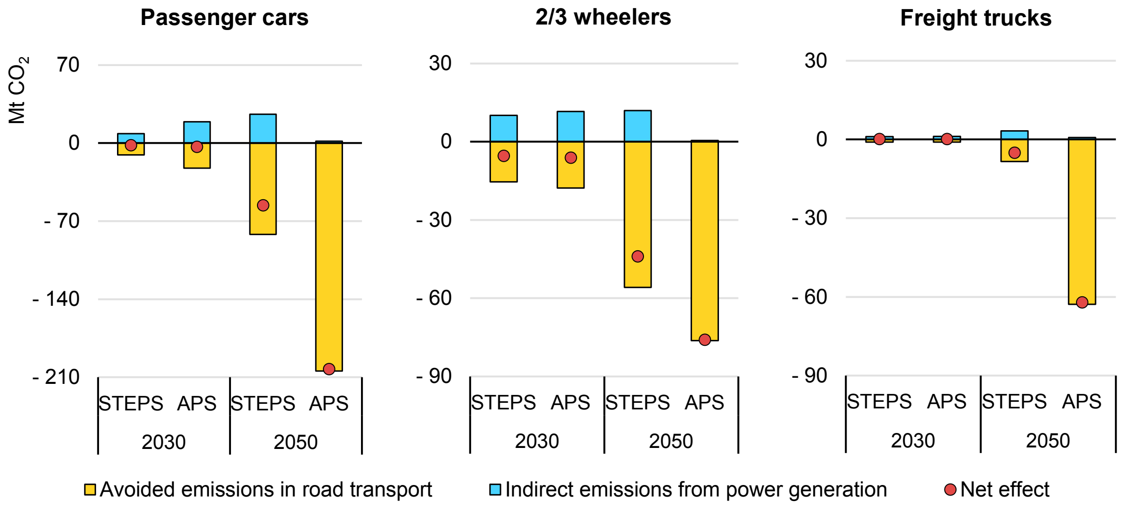
Figure 3.8 Additional CO_2 mitigation potential in the APS compared to the STEPS by abatement option, 2010-2050



Today, such indirect emissions from EVs and avoided emissions from displaced oil consumption roughly offset each other. In 2021, India's EV fleet consumed 1.3 TWh, creating over 1 Mt CO_2 indirect emissions, while displacing about 0.12 Mtoe oil consumption. Going forward, indirect emissions are set to rise, as the increase in electricity consumption outpaces India's power sector decarbonisation. The carbon intensity of electricity generation improves by 25% up to 2030 in both scenarios, but EVs are deployed more rapidly in the APS and consume 60% more electricity compared to the STEPS. As a result, indirect emissions in 2030 increase to about 25 Mt CO_2 in the STEPS and more than 40 Mt CO_2 in the APS. Due to an accelerated power sector decarbonisation after 2030, indirect emissions peak in the APS around 2035 and fall to less than 5 Mt CO_2 by 2050. By contrast, in the STEPS, indirect emissions continue to increase until 2050 to 50 Mt CO_2. However, the avoided tailpipe CO_2 emissions from the growing EV fleet are larger than indirect emissions from the power sector, leading to net emissions avoidance in both scenarios. In 2030 India's EV fleet avoids around 5 Mt CO_2, while in 2050 110 Mt CO_2 is avoided in the STEPS and 380 Mt CO_2 is avoided in the APS.

Emissions avoidance potential varies by vehicle category (Figure 3.9). In the STEPS, the fleet of nearly 5.5 million electric passenger cars avoids emissions of 2 Mt CO_2 in 2030; in the APS a fleet more than twice as large avoids about 3.5 Mt CO_2 in the same year. In the APS by 2050, a nearly fully decarbonised power sector means that the 180 million electric passenger cars avoid 200 Mt CO_2, almost four times more than in the STEPS. Two- and three-wheelers already avoid around 5 Mt CO_2 in both scenarios in 2030, and up to 75 Mt CO_2 by 2050. Electric freight trucks do not start avoiding emissions until the mid-2030s but have great potential to substantially contribute to decarbonisation in the long run. In 2050, one truck could avoid, on average, 15 t CO_2 in in the STEPS and nearly 35 t CO_2 in the APS. As India's electric truck fleet in 2050 is almost six times larger in the APS than in the STEPS, it avoids more than 60 Mt CO_2, compared to 5 Mt CO_2 in the STEPS.

Figure 3.9 Indirect and avoided CO_2 emissions from EVs by vehicle category in the STEPS and APS, 2030 and 2050



Assessing the environmental performance of EVs with a well-to-wheel approach considers the life cycle of the fuels involved, already covering the large majority of a vehicle's emissions. In an additional analytical step, life cycle assessment of vehicles also considers emissions that arise from a vehicle's manufacturing, use and end-of-life treatment, including raw materials (ITF, 2020). Such assessments show that among different technologies, electric cars have the lowest climate impact. An electric car registered in India in 2021 could emit about 20% less GHG emissions than a conventional gasoline-fuelled car. Electric cars registered in 2030 could emit 30% to 56% less GHG emissions over their entire life cycle, depending on how rapidly the power sector decarbonises (ICCT, 2021d).

Box 3.1 Environmental impacts of India's power sector

In 2021, coal-fired power plants provided nearly 75% of the 1 690 TWh of electricity generated in India. Reflecting the high reliance on coal, the carbon intensity of electricity stood at 710 g CO_2/kWh in the same year, 50% above the global average. The power sector emitted half of India's energy-related CO_2 emissions (1.2 Gt CO_2) in 2021, in addition to substantially contributing to local air pollution. India's power sector was responsible for half of total sulphur dioxide (SO_2) emissions, 30% of NO_X and 10% of combustion-related $PM_{2.5}$ in 2021.

In November 2021, India's Prime Minister announced a set of targets for the power sector, along with the long-term goal of reaching net zero carbon emissions in 2070. He strengthened the 2030 target for non-fossil fuel power generation capacity from 450 GW to 500 GW, and pledged that 50% of the capacity will stem from renewable sources in 2030. India's government has been further working on adopting stricter environmental standards for thermal power plants since 2015 to reduce air pollutant emissions. However, the standards for NO_X were relaxed considerably in 2020 and compliance deadlines have been repeatedly delayed, most recently in 2022 when the MoEFCC granted an extension up to 2026. If implemented, these norms would set similar emissions standards to those in China and the United States, while EU standards remain stricter.

India's environmental and climate policies have the potential to considerably reduce CO_2 and air pollutant emissions from power generation. In the STEPS, nearly 75% of the 5 300 TWh generated in 2050 comes from renewables, including large hydropower plants, which decreases CO_2 emissions by 25%, compared to 2021. The installation of adequate emission control technologies in thermal power plants could slash SO_2 emissions by 95% and reduce nearly 90% of $PM_{2.5}$ by 2030 compared to 2021 levels, though a significant amount of NO_X emissions remains. In the APS, the share of renewables in India's electricity mix is 75% by 2040 and nearly 90% by 2050. This could slash the carbon intensity of electricity to less than 30 g CO_2/kWh by 2050, leading to a drop in CO_2 emissions of 90%. The emissions of all air pollutants are greatly reduced by 2050 in the APS.

Sources: CSE (2020), MoEFCC (2015), MoEFCC (2020), PowerLine (2022).

Air pollution

Road transport contributes significantly to India's air pollution challenge, notably by emitting NO_X and PM. Given that a large share of the emissions are in urban areas, and hover close to the ground, and that large numbers of people are exposed to this pollution, reducing transport-related air emissions can result in direct public health benefits.

Air emissions

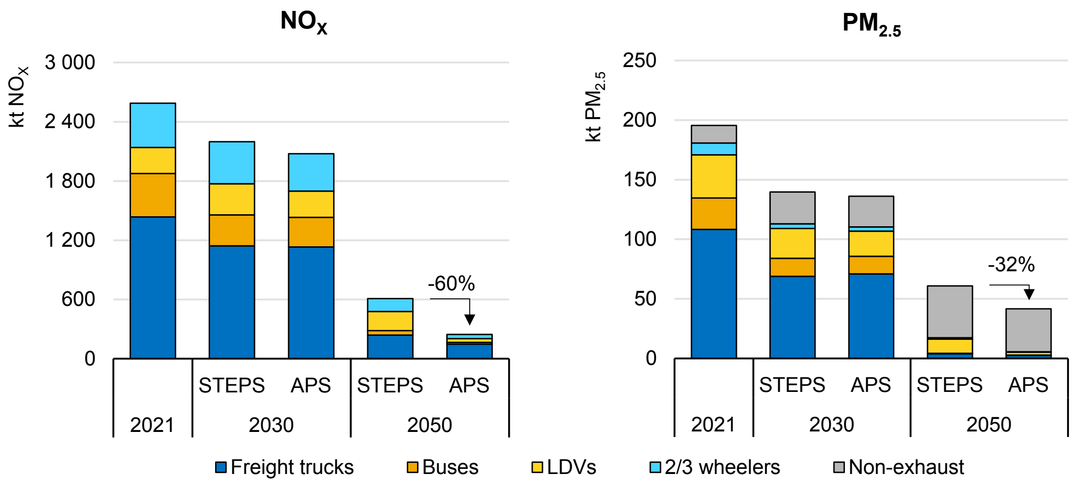
India's road transport sector emitted 2.6 Mt NO_X in 2021, about one-third of India's total NO_X emissions. NO_X, travelling by air, can transform into $PM_{2.5}$, and thereby contribute to high $PM_{2.5}$ concentration levels. The road sector also emitted about 0.2 Mt $PM_{2.5}$, accounting for 5% of nation-wide energy-related $PM_{2.5}$ emissions.

This seemingly low share is a result of India's reliance on solid biofuels for residential cooking, accounting for 45% of India's national $PM_{2.5}$ emissions in 2021. In addition, the contribution of road transport to urban air pollution can be considerably higher than national average.

The majority of NO_X and $PM_{2.5}$ emissions come from diesel-fuelled vehicles which emit higher amounts of air pollutants than other ICEs. Trucks and buses, the largest consumers of diesel fuel, jointly account for about 70% of all the NO_X and $PM_{2.5}$ emissions from road transport. Two-wheelers are also a considerable source of NO_X pollution, accounting for more than 15% of transport-related NO_X emissions in 2021. $PM_{2.5}$ is not only emitted through fuel combustion but also through road, brakes and tyre wear abrasion, classified here as vehicle-related, non-exhaust emissions. Such emissions account for 8% of total vehicle-related $PM_{2.5}$ emissions (Figure 3.10).

India's policies are projected to reduce air pollutant emissions substantially. In both scenarios, road-transport related NO_X emissions decline by 15-20% up to 2030 then fall drastically afterwards. By 2050, NO_X emissions are 75% below the 2021 level in the STEPS, or 90% lower in the APS (where more trucks and cars transition to low-emissions technologies, notably EVs).

Figure 3.10 Road-related air pollutant emissions in the STEPS and APS, 2021-2050



Vehicle-related $PM_{2.5}$ emissions are projected to fall by 70% in the STEPS and by 80% in the APS by 2050. A more ambitious policy framework as assumed in the APS could principally eliminate exhaust $PM_{2.5}$ emissions by 2050 through higher adoption of low-emission technologies (notably electrification) by trucks. By contrast, non-exhaust emissions from road, brakes and tyre wear abrasion continue to increase with the growing vehicle fleet. The extent of such emissions as well as the suspension of road dust strongly depend on local conditions. Abatement cannot be achieved through fuel or powertrain switches within the vehicle fleet. However, addressing both is necessary to improve ambient air quality in India (Box 3.2).

Box 3.2 Addressing non-exhaust PM emissions and road dust suspension

Non-exhaust emissions along with the suspension of road dust are the dominant sources of India's road-transport related PM emissions. Non-exhaust emissions are directly linked to a vehicle's make-up and use, stemming from the continuous abrasion of road surfaces, brakes and tyres, making relatively accurate quantification possible. These sources are estimated to have contributed 8% to transport-related $PM_{2.5}$ emissions in 2021 (Figure 3.10).

Suspension of deposited road dust through traffic-induced turbulence is a major, direct contributor to PM and thus poor air quality. Re-suspended particles are a mixture of PM emitted through exhaust or non-exhaust road transport activities as well as any other deposition from sources such as construction sites or soil abrasion. Such particles are difficult to quantify due to the lack of specific emissions factors and, being not directly energy-related, are not included in the IEA's estimates. As dust suspension and non-exhaust emissions from road transport can mutually reinforce each other, to avoid double counting they should not be interpreted as exclusively complementary.

The extent of dust suspension varies with the amount of silt or sand deposited on the road, surrounding land use patterns, climatic conditions, road types (paved vs. unpaved) and materials used, as well as road activity, including the speed, number and size and weight of vehicles. It is estimated that road dust contributed nearly a quarter of India's road-transport related $PM_{2.5}$ emissions in 2016. On average, it is responsible for one-third of urban PM_{10} emissions, with higher levels in major cities such as in Delhi (about 55% 2014) Mumbai (more than two-thirds in 2021) and Bangalore (50% in 2022).

While regulations for exhaust emissions from vehicles are becoming more stringent globally, non-exhaust PM emissions remain largely unregulated. As a result, the share of PM emissions from non-exhaust sources has increased in recent years and are expected to be responsible for most of the PM emissions from road traffic in the coming years. Excluding dust suspension, India's vehicle-related, non-exhaust $PM_{2.5}$ emissions are expected to double by 2030 in both the STEPS and APS. By 2050, non-exhaust sources account for at least three-quarters of $PM_{2.5}$ emissions from road transport if remaining uncontrolled (Figure 3.10). While eliminating exhaust emissions, EVs cannot substantially reduce non-exhaust emissions. In fact, these emissions could be even higher for EVs relative to a comparable ICE model, as heavy batteries typically increase the vehicle's weight.

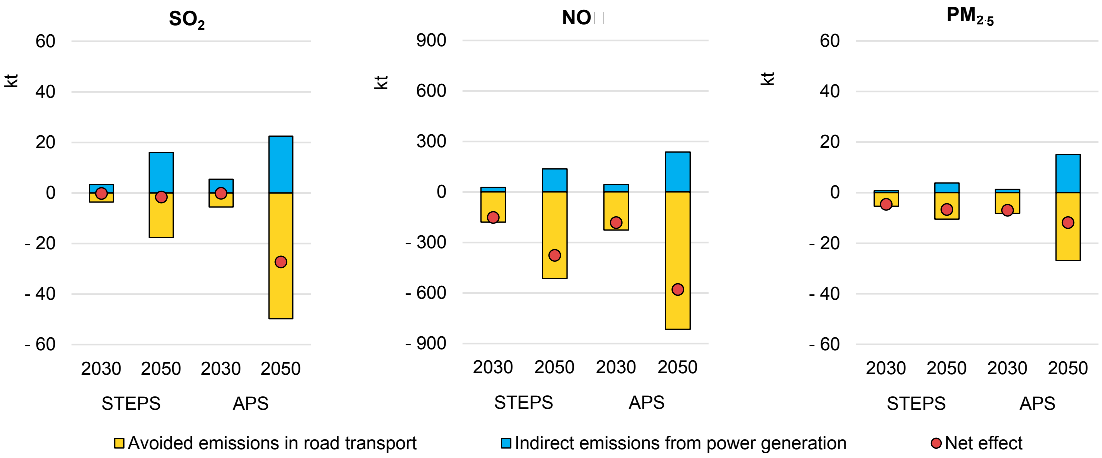
Measures to address non-exhaust and road dust-related transport emissions include:

- Street washing, e.g., with water sprinkling systems in the early morning hours before peak traffic. While this is the most effective way to deal with immediate dust control, this measure might face serious resource pressure in arid regions.
- Reducing overall traffic volumes, e.g., by promoting public transport and active mobility, or by implementing distance-based charges or congestion pricing. Such measures can effectively lower urban PM pollution during peak hours.
- Improving road conditions, including solid pavement and under-structures when building roads, regular maintenance and strict regulation to limit truck loads.
- Improving traffic management to reduce idle time at traffic junctions or stop lights, e.g., with Intelligent Traffic Management Systems.
- Requiring regenerative braking systems, tarpaulin coverage for trucks, and tyre composition regulation.
- Replacing dusty kerbsides with green vegetation and prohibiting road-side storage of construction materials.

Sources: Bhalerao, S. (2021), CSTEP (2022), Eionet (2021), IIT Kanpur (2016), Karanasiou, A. et al. (2014), Klimont, Z. et al. (2002), OECD (2020), Singh, N. et al. (2021).

Like CO_2 emissions, road transport electrification also causes indirect air pollution through emissions at the power plant level. Switching from petroleum products to electricity can immediately avoid the net emissions of NO_X and $PM_{2.5}$. By 2030, road transport electrification could avoid 0.15 to 0.18 Mt NO_X, depending on the pace of electrification, and lead to $PM_{2.5}$ emission reductions. As for SO_2, EVs will still cause net emissions in the coming years. By 2030, however, when India's environmental standards for coal-fired power plants are assumed to be fully implemented, EVs reach a turning point and start avoiding SO_2 emissions as well. In the long run, in both scenarios, India's electricity mix is dominated by renewable energy sources and EVs have the potential to avoid substantial amounts of air pollutant emissions.

Figure 3.11 Avoided and indirect air pollutant emissions from EVs in the STEPS and APS, 2030 and 2050



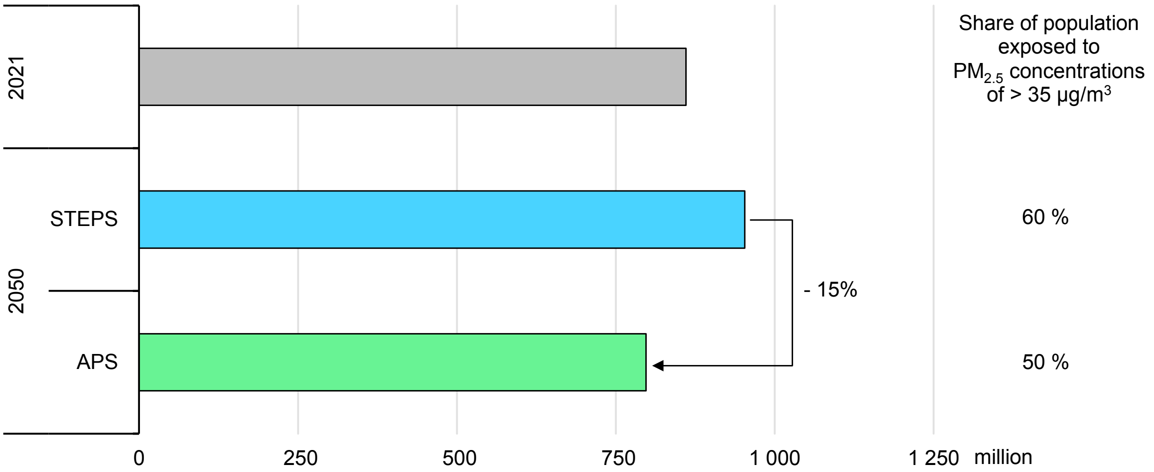
Ambient air pollution and health impacts

India suffers from some of the highest levels of ambient air pollution globally. The IEA estimates that in 2021, more than 850 million people were exposed to $PM_{2.5}$ concentrations averaging more than 35 µg/m^3 per year (Figure 3.12). Exposure to such high levels of air pollution has serious consequences for human health, leading not only to acute respiratory issues but can also be linked to ischemic heart disease, stroke, pneumonia and lung cancer (WHO, 2022). In 2021, nearly one million premature deaths in India could be attributed to ambient PM pollution.

The contributions from road transport to air pollution are particularly high in densely populated areas. It is estimated that around 123 000 premature deaths were caused in 2015 through the contributions of transport and anthropogenic dust[10] to $PM_{2.5}$ concentrations (HEI, 2018). The IEA estimates that under the current policy framework, India can reduce the share of its population exposed to $PM_{2.5}$ concentrations of more than 35 µg/m^3 to 60%. Even so, by 2050 more than 950 million people are expected to die from such heavily polluted air. In the APS, however, the rapid switch to low-emissions technologies in transport and other sectors reduces this number by 15%.

[10] Anthropogenic dust is defined here as dust from fugitive, combustion and industrial activities, and suspension from paved and unpaved roads, mining, quarrying, and agricultural operations (HEI, 2019).

Figure 3.12 Population exposed to $PM_{2.5}$ concentrations of >35 μg/m³ in the STEPS and APS, 2021 and 2050



IEA. CC BY 4.0.

Chapter 4. Priority areas for action

This chapter presents key areas for action that would allow India to accelerate its transition towards more environmentally sustainable road transport in line with national long-term climate goals, reflected in the pathway projected in the APS. The proposed action areas are structured by topic and include measures that India could consider implementing in the short-, medium- and long-term. They are based on the IEA's scenario analysis, stakeholder consultations and literature review, and contain additional quantitative analysis to shed light on the potential benefits they could bring.

The potential actions India could take are as follows:

- strengthening the basis for transport policy making
- strengthening fuel economy standards for passenger cars and two-wheelers
- improving the targeting of support policies for EVs, based on total cost of ownership (TCO) analysis
- strengthening EV financing
- transitioning the freight truck fleet
- adopting actions to reduce air pollution
- step up international collaboration and engagement efforts.

Strengthening the basis for transport policy making

There are several steps that countries can take to strengthen the basis for transport policy making. These include establishing clear targets and goals, building capacity for long-term planning and securing consensus on long-term goals, building strong institutional structures for horizontal and vertical co-ordination, and strengthening transport data collection and management.

The establishment of clear targets can provide strong guidance for the sector. In China, for example, the NEV credit mandate, introduced in 2017, has been a powerful driver of EV sales. It set annual ZEV credit targets for manufacturers as a percentage of their annual vehicle sales. In 2020, the programme and its targets were extended to 2023, by which the target will be 18% (16% in 2022, 14% in 2021). Targets can also be extended to include infrastructure; in the European Union, member countries are required to set deployment targets for publicly accessible EV chargers for the decade to 2030, with an indicative ratio of one charger per ten electric cars. The EU Green Deal extends the target further to one million publicly accessible chargers installed by 2025 and set out a roadmap of key actions to achieve it. Setting targets will inspire confidence in global and national OEMs about the potential product pipeline in India, allow state and national governments to plan incentives accordingly and overall provide clarity and robust decision-making.

India currently needs an overarching plan or vision for the transport sector; its last national level transport plan dates to 2010. India's updated NDC does not include sectoral emissions trajectories, and a framework that defines sectoral contributions to the 2070 goal has not yet been developed. Nonetheless, India acknowledges the importance of developing a long-term low-carbon development strategy for the transport sector. Reviving long-term planning, integrated with other transport modes such as rail, aviation and waterways, along with the alignment of transport policy with urban planning, infrastructure and other investments could contribute to a clear vision for the sector and outline different pathways for how this can occur.

Strong institutional structures play an important role in ensuring effective co-ordination and collaboration across sectors and levels of government. Historically, the large number of institutions with responsibilities relevant to road transport planning, regulation and investment has favoured project-based planning and transport mode silos (NTDPC, 2014). Such an approach may increase costs and limit the benefits of individual policies. For example, co-ordination and alignment of key regulatory processes such as fuel economy standards which are regulated by the BEE, and exhaust emission standards which are regulated by MoRTH, could help improve policy predictability and reduce compliance costs for industry. As for electrification, India could consider creating a task force or nodal agency to lead and guide EV-related policy making (see Box 4.2, which could also help align or more strongly connect policy instruments such as fuel economy standards or the scrappage programme with EV development.

Given that transport is a concurrent policy area, effective co-ordination mechanisms are needed between the national, state and city levels. India can draw from its experience with electricity governance reforms, where new institutional structures were created to improve distribution infrastructure, achieve a higher share of renewables, and promote energy efficiency while keeping electricity affordable.[11] Performance metrics on vehicle electrification could be linked to financing assistance from the central government to states and respective line ministries to facilitate the roll-out of EVs and charging infrastructure. Some sub-national entities, such as Mumbai, have created expert committees to improve collaboration among government, industry and business

[11] The Forum of Regulators, for example, offers a platform for state and national institutions to exchange information about common challenges and policy reforms. In addition, the Ministry of New and Renewable Energy appointed state nodal agencies to co-ordinate state action on renewable energy.

experts, so-called "EV Cells" (WRI India, 2022). NITI Aayog is planning to institute 100 EV Cells across the 100 SMART cities to include transport planning as one of the mandates for these cities. Similar bodies could be established in all states, with national forums where these committees could exchange information about common challenges and best practices.

Finally, dynamic transport analysis and policy planning require comprehensive and accurate data. Available estimates for key indicators such as vehicle activity, energy use and emissions stemming from different transport modes and vehicle categories vary widely (ICCT, 2022a). Some analysts have called on India to mandate an institution to collect, treat and disseminate transport-related data, statistical analysis and associated information (ICCT, 2022a). This could include conducting periodic national-level transport surveys to gain a better understanding of trends and policy impacts on mobility patterns.

Box 4.1 Setting up effective institutional arrangements at sub-national levels in London and California

London, UK has set a goal to achieve zero-emission transport by 2050 and to have at least 30% of new vehicle sales to be zero emission by 2030. The Mayor's Transport Strategy for London sets out a list of actions to achieve this. To support the strategy's implementation, an EV Infrastructure Taskforce was set up in 2018, comprising taxi stakeholders, car manufacturers and EV infrastructure investors. The task force has informed and steered the development of a delivery plan to identify how, when, and where to increase London's EV infrastructure up until 2025.

California, US has been a leader in climate policies globally, and serves as a good example for state level governance reforms to promote vehicle electrification. Its first Zero-Emission Vehicle (ZEV) Action Plan directed the California Air Resources Board, Energy Commission and Public Utilities Commission to work with the Plug-in Electric Vehicle Collaborative and the California Fuel Cell Partnership to meet the long-term target of reducing transportation-related GHG emissions by 80% below 1990 levels by 2050. The Governor's Office established an inter-agency working group which included these stakeholders as well as the Governor's Office of Planning and Research, the Governor's Office of Business and Economic Development, the California Independent System Operator and eight other State agencies for the development of the ZEV Action Plan. The Governor's Office used a "SmartSheet" to track progress for each agency on each of the ZEV actions, enhance transparency and share resources.

Source: California Governor's Office (2022), City of London (2019).

Strengthening fuel economy standards

Fuel economy standards have been one of the key policy instruments that governments have put in place to promote vehicle efficiency improvements. In addition to increasing the fuel efficiency of conventional vehicles, fuel economy standards can accelerate the adoption of zero- and low-emission vehicles (ZLEVs).

To date, India has implemented fleet average fuel economy standards, the so-called Corporate Average Fuel Economy (CAFE) standards, for passenger cars. These have been overachieved by industry (see Chapter 2) and have therefore had little effect on bringing ZLEVs to the market. To increase fuel efficiency, two potential actions are explored in the following section: i) increasing the stringency and improving the design of fuel economy standards for passenger cars and ii) implementing fuel economy standards for two-wheelers, designed to drive the uptake of electric models. Enforcing fuel economy standards will also be critical for heavy-duty transport, in particular freight trucks, as discussed below.

To bring about the greatest benefits, fuel economy standards need to be set at sufficiently stringent levels. Once implemented, the standards should be updated and tightened regularly to keep pace with technology development and achieve greater emissions reductions, while still giving manufacturers time and transparency to plan production according to new, more stringent regulation. Regulators and policy makers need to ensure that regulations are based on, and translate to, real-world performance. Continued monitoring of the gap between rated and real-world performance is needed to ensure that fuel economy standards remain achievable have their intended impact. Digital technologies can lower costs and increase effectiveness of compliance monitoring, which should then inform future regulations. Introducing penalties and transparently communicating industry's performance can help increase compliance with the standards. Integrating the fuel economy standards and their revision cycle with other key regulatory processes, such as exhaust emission and fuel quality norms, help simplify the regulatory landscape and support convergence on zero-emission vehicle (ZEV) goals.

Strengthening fuel economy standards for passenger cars

The first phase of India's national CAFE standards for passenger cars took effect in 2017, requiring manufacturers to meet a target of 130 g CO_2/km on fleet average. However, they were not sufficiently stringent to spur significant improvements in fuel economy (ICCT, 2021a), nor to drive EV sales (The Economic Times, 2022d). In April 2022, Phase II standards took effect, tightening the target to 113 g CO_2/km. Three measures could strengthen the regulation's environmental effectiveness: An update that tightens the standards by 2027, followed by regular revisions in cycles of five to eight years; a revision of the current "super-credit scheme"; and stricter enforcement in case of non-compliance. In addition, switching to the global standard testing procedure for determining fuel economy performance before updating the standards, and aligning the update with revision rounds of the BS standards, could facilitate the adoption process and reduce costs for industry.

Updating the existing CAFE standards for passenger cars

Until recently, the fuel economy of newly sold passenger cars had closely followed that of European passenger car models. However, a gap emerged as the European Union (EU) adopted more stringent regulations (ICCT, 2022b). In 2009, the EU set a fuel economy standard for passenger vehicles of 130 g CO_2/km to be met by 2015 and a target of 95 g CO_2/km for 2021 (EU, 2009). It updated the regulation in 2019, setting new targets: The 2021 standards were tightened by 15% in 2025 and by 37.5% in 2030 (EU, 2019). In addition, the EU's "Fit for 55" package, released in 2021, proposed tightening standards by 55% in 2030. It also included a reduction target of 100% by 2035, which effectively means that all new car (and van) sales should be ZEVs as of 2035 (European Council, 2022).

The STEPS projects only marginal fuel economy improvements in the coming years and an enhancement of less than 20% until 2035, driven by policies that promote the uptake of alternative powertrains, notably EVs. For an accelerated transition that helps India's road transport sector contribute to its long-term climate goals, fuel consumption per km would need to fall by more than 50% by 2035. To achieve this, India could consider updating national CAFE standards, for example by tracing EU norms with a time lag, as follows:

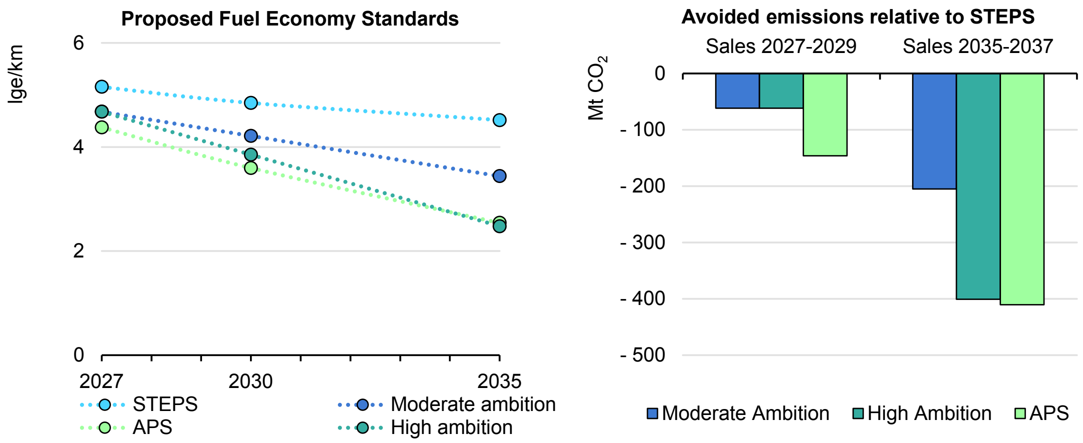
- 2027 target: a 15% reduction of corporate average fuel economy from 2022 levels (following the EU's target set in 2019)
- 2035 target, moderate ambition: a 37.5% reduction from 2022 levels (following the EU's target set in 2019)
- 2035 target, high ambition: a 55% reduction of corporate average fuel economy from 2022 levels (following the EU's target proposed in the Fit for '55 package).

Strengthening the existing CAFE regulation in 2023 with updated targets for 2027 and 2035 gives manufacturers sufficient time to align upcoming vehicle models with future standards. Such planning capability and predictability are critical to enable compliance and an economically sustainable transition for the car industry.

If India were to achieve a 15% reduction in corporate average fuel economy from 2022 levels by 2027, passenger vehicles estimated to be sold between 2027 and 2029 would, over their entire lifetime, save 20 Mtoe fuel and thereby avoid more than 60 Mt CO_2, relative to the current policy framework, as modelled in the

STEPS. With the moderate ambition target for 2035, passenger vehicles sold between 2035 and 2037 could save 70 Mtoe fuel and avoid 205 Mt CO_2 over their lifetime. Under the high ambition approach, targeting a 55% reduction, these savings are twice as large. Following this trajectory could align the fuel economy enhancements of the passenger cars, with a pathway that allows the road transport sector to realise its required contributions to India's net zero 2070 goal (Figure 4.1).

Figure 4.1 Avoided emissions of updated CAFE standards of passenger cars



Revising flexibility mechanisms

India's current CAFE regulation allows for so-called "super credits", meaning that the fuel economy of certain ZLEVs is weighted more in a manufacturer's calculated CAFE relative to a conventional ICE (MoRTH, 2018a). An EV is triple counted, a plug-in hybrid counts 2.5 times and a hybrid twice. In addition, "eco-innovations" including regenerative braking, a start-stop system or a tyre pressure monitoring function are rewarded by being counted as extra credit points. As these technologies are nowadays extensively used by manufacturers, such credits make it significantly easier to meet individual corporate targets (ICCT, 2021a). Furthermore, while super credits can help ZLEVs enter the market in the early stages of development, they risk undermining the standard's potential to drive vehicle efficiency improvements, if not regularly adjusted to technology innovation and market developments (GFEI, 2017).

When updating CAFE standards, India could consider withdrawing credit points for widely-applied technologies such as start-stop systems, and replacing them with credit points for innovative high-emissions abatement methods. One challenge in India's context is the country's high temperatures, which can increase air conditioning needs. Impacts from this could be addressed through regulating refrigerants with high global warming potential (gwp) used in vehicles for air conditioning as well as potentially providing credit points for manufacturers deploying low-gwp refrigerants. Here, faster adoption may be facilitated by the global nature of India's motor vehicle industry, with manufacturers already exporting vehicles which meet low-gwp refrigerant regulatory requirements. Further, the BEE could consider revising the current, generous "super-credit" scheme for EVs and hybrid models to strengthen the standard's potential to push more ZLEV models in the market (CSE, 2021). In the EU, for instance, the incentive mechanism for ZLEVs was gradually phased down until 2022 and it will transition in 2025 to a scheme allowing for the relaxation of a manufacturer's specific emission target, if the company exceeds a ZLEV sales share of 15% by 2025 and 35% by 2030 (EC, 2022).

Addressing non-compliance

Current regulations do not specify punitive measures in the case of a manufacturer's non-compliance with CAFE standards, apart from a reporting obligation to ministries in charge (MoRTH, 2018b). This has reduced transparency with respect to the potential financial consequences of non-compliance for manufacturers and increases the incentive to deviate from standards. While all manufacturers complied with their individual corporate fuel economy targets, ranging within 121-184 g CO_2/km in the reporting period 2020-21 (MoRTH, 2021a), compliance may become more difficult and costly for the tightened standards of 103-148 g CO_2/km in the second phase, increasing the risk of non-compliance (The Economic Times, 2022d). With the adoption of the Energy Conservation (Amendment) Bill in 2022, India has laid the foundation for the implementation of a transparent, concrete financial penalty of sufficient magnitude in the case of non-compliance to updated CAFE standards to serve as a strong deterrent to exceeding the standards. The act's proposed penalty would require manufacturers to pay INR 25 000 (USD 336) per vehicle for exceeding standards by up to 0.2 lge/100km and INR 50 000 (USD 673) for exceeding standards by more than 0.2 lge/100km (Lok Sabha, 2022).

Aligning testing cycles with international standards

Testing procedures are a critical element in the measurement of vehicle fuel consumption and emissions, and hence for determining a new model's fuel economy. Testing procedures currently vary significantly between jurisdictions, making it difficult for policy makers and manufacturers to compare the stringency of standards. The United Nations Economic Commission for Europe has developed chassis dynamometer tests for the determination of emissions and fuel consumption from light-duty vehicles that seek to represent typical driving characteristics around the world, the "Worldwide Harmonised Light Vehicles Test Procedure" (WLTP) (TransportPolicy.net, 2018). These were adopted by the EU in 2017, replacing the "New European Driving Cycle" (NEDC) (EU, 2017). While remaining a laboratory test, the WLTP significantly improves the simulation of real-world driving conditions and eliminates many practices that manufacturers have used to artificially lower tested fuel consumption. Hence, adopting the WLTP is an important step to ensure that the environmental limits set by regulations are implemented (T& E, 2017).

India might consider switching from its current driving cycle and testing procedure to the WLTP before revising fuel economy standards because the new standards would need to be revised again shortly after their implementation.[12] This would substantially increase the robustness of the testing protocol and ultimately help achieve the real emissions reductions targeted by the standards. For instance, China moved in 2021 to fuel economy standards which are based on the WLTP for passenger cars (ICCT, 2021e). India is expected to move in April 2023 to Real-Driving Emissions (RDE) which pivot the measurement of air pollutant emissions for BS-VI standard compliance from lab to real-world road conditions. While CAFE and BS standard compliance are not directly linked, this switch might have co-benefits for the CO_2 emissions reduction potential of vehicles (The Economic Times, 2022d).

Fuel economy standards for two-wheelers can drive forward electrification

At present, there are no fuel economy standards in place for two- or three-wheelers in India. In the case of the former, however, the matter is receiving increasing consideration by the BEE, reflecting the high numbers of vehicles, the increasing use of larger and more powerful engines and low levels of electrification. In 2022, fewer than 2% of two-wheeler sales were electric, in comparison with 40% of three-wheelers (Box 2.1).

There is an important opportunity to set the standards in a way that drives forward electrification. Standards need to account for the savings which can be achieved by conventional technologies and what is needed to drive forward electrification. The average emissions of the current fleet of two-wheelers amount to 36 g CO_2/km, and research suggests that a 20-25% improvement in efficiency for new vehicles can be achieved with ICE technology improvements alone in both the motorcycle and scooter fleets (ICCT, 2021f). A fleet average target therefore needs to be lower than this if it is intended to promote electrification.

The APS suggests that fuel efficiency for newly sold two-wheelers must improve by 40% by 2030 from 2022 levels to bring the two-wheeler fleet on track to

[12] As the WLTP's testing procedures are stricter than India's current driving cycle, a standard measured with the WLTP would need to be set higher than the one under present procedures to enforce the same environmental limits. Updating the testing procedures therefore also brings about a "conversion" of the standards set.

contribute to India's long-term net zero goals. This efficiency improvement would bring down tailpipe CO_2 emissions of newly sold two-wheelers to less than 14 g CO_2/km. While a 40% improvement can be viewed as ambitious, it is consistent with recent research which highlights the opportunity of cost-effective measures – including electrification – to achieve up to a 50% improvement (ICCT, 2021f). Under the APS, sales of electric two-wheelers are 60% of market share by 2030.

If India were to achieve a 40% improvement in vehicle efficiency from 2022 levels by 2030, two-wheelers sold between 2025 and 2027 could, over their entire lifetime, save almost 4.5 Mtoe of fuel and avoid 13 Mt of tailpipe CO_2 emissions, compared with India's current policy framework (STEPS). Looking to 2035, under the APS, electric two-wheelers dominate vehicle sales at nearly 80% of the market share. For two-wheelers sold between 2035 and 2037, the savings over their entire lifetime would be 15 Mtoe of fuel, and result in a reduction of an additional 40 Mt CO_2 compared with the current policy framework.

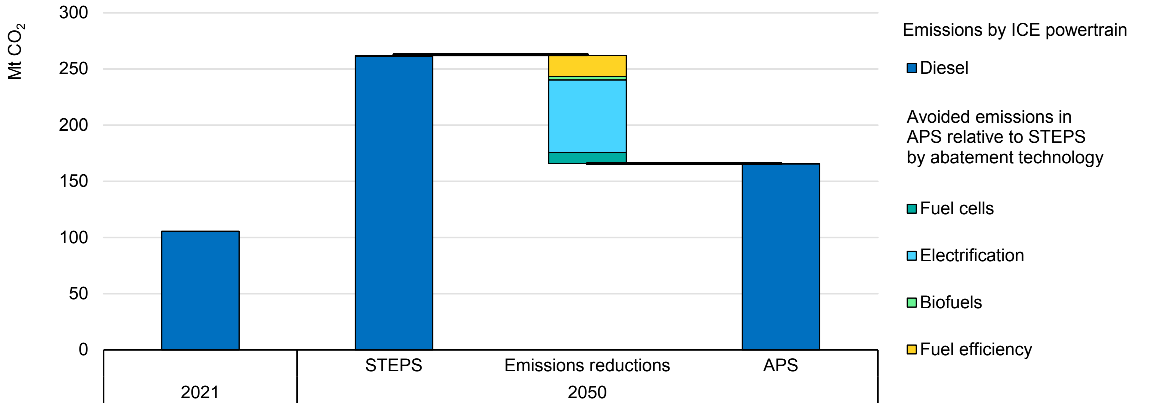
Transitioning the freight truck fleet

Addressing the emissions from heavy freight transport is critical in improving air quality. As shown in Chapter 3, the IEA estimates that the freight activity of trucks could quadruple between 2021 and 2050, with associated fuel consumption and environmental impacts. Heavy freight trucking is regarded as a "hard-to-abate" sector, meaning that mature technological solutions for decarbonisation are not yet readily available. Reflecting this, diesel is projected to remain the dominant fuel in both scenarios until 2050.

A comparison of the impact of India's currently stated policies, as reflected in the STEPS, with a more ambitious scenario (APS) that brings road transport on track with India's net zero 2070 goal, shows that additional efforts are required to reduce the energy demand and emissions from freight trucks. While India's truck fleet is estimated to reach about 11 million vehicles by 2050 in both scenarios, the powertrain technologies deployed vary, with a considerably higher number of electric and hydrogen-fuelled trucks in the APS. By 2050, India's fleet could have 2 million electric and hydrogen trucks more in the APS than in the STEPS; they would make up nearly a quarter of the fleet. In addition, diesel trucks sold in 2050 would be on average 15% more fuel efficient in the APS than in the STEPS, and a higher biofuel blending in ICE trucks leads to 10% more biofuel use.

The differences in fleet composition and fuel economy critically impact the fuel consumption and environmental outcomes of India's truck fleet. As shown in Figure 4.6, energy consumption by freight trucks in the STEPS increases from 35 Mtoe to more than 90 Mtoe between 2021 and 2050 and is met through diesel consumption. In the APS, stronger fuel efficiency improvements and an aggressive deployment of ZEV trucks limit energy consumption growth to about 70 Mtoe by 2050, with low-carbon fuels accounting for nearly half of this growth. As a consequence, while CO_2 emissions in the STEPS almost triple over the same period to 260 Mt CO_2, growth in the APS is curbed to 165 Mt CO_2 (some 35% below the STEPS level). A switch to electric trucks, more prominent for MFTs, makes up nearly 70% of the additional tailpipe CO_2 emissions avoided, fuel economy improvements account for almost 20%, and the deployment of hydrogen-fuelled vehicles (notably as HFTs) for 10% (Figure 4.6).

Figure 4.2 Emitted and avoided CO_2 emissions from freight trucks by powertrain between STEPS and APS, 2021 and 2050



Continued improvement of fuel efficiency will be critical, as diesel ICEs account for 90% and 75% of the truck fleet in the STEPS and APS scenarios for 2050, respectively. By then, the fuel efficiency of the diesel truck fleet must improve by more than 35% to follow a trajectory required to be in line with India's long-term climate ambitions. The update and effective implementation of adopted fuel economy standards for trucks is therefore an immediate priority. If the fuel economy of diesel trucks were to stall at today's level, the fuel consumption and CO_2 emissions of India's diesel truck fleet would be 10% higher in 2030 than in the STEPS.

In 2017, India adopted fuel economy standards for HDVs (with a GVW > 12 t). However, they were never enforced (see Chapter 2). Standards were set to be implemented in a two-phase approach, but enforcement of Phase-II had been put on hold and in November 2022, MoRTH re-notified Phase-I standards to be implemented in 2023 (MoRTH, 2022c). Further, the BEE published in 2022 an opening to conduct a market study and submit a proposal for the revision of fuel economy standards for heavy-duty vehicles (BEE, 2022). As outlined in previous sections, fuel economy standards can – if sufficiently stringent, enforced and regularly updated – help push lower-emission technologies into the market.

Mandated fuel efficiency gains could be achieved through a range of technologies. Reducing idling is one option. Investment in better vehicle design, such as improved aerodynamics, reduced-rolling resistance for tyres and truck weight reduction, often pays off within a few years. Making improvements to engines, transmissions and drivetrains also brings down fuel consumption (IEA, 2017). However, these have longer payback times than operators tend to consider when purchasing new trucks, and may therefore require stronger policy incentives. Recent analysis of medium freight trucks found that per-vehicle fuel consumption reductions of up to 30% are possible with cost-effective technologies that provide a return on the initial capital investment within one to two years (ICCT, 2019).

While essential, fuel efficiency improvements in ICEs will not be sufficient to achieve emissions reductions in line with India's net zero 2070 goal. The availability and use of low-emissions fuels, biofuels, electricity and hydrogen, will also need to be scaled up rapidly. In the STEPS, low-emission trucks (electric and hydrogen models) only have a small market share and biofuels make up less than 5% of their fuel consumption by 2050. Only the MFT stock partially transitions to CNG with such vehicles accounting for 15% of the MFT fleet in 2050. This picture strongly differs in the APS, where electric and fuel cell models would account for nearly 60% of truck sales in the same year while CNG plays a smaller role. The use of biofuels per ICE truck would be twice as much as in the STEPS. While the impact on the emissions of low-emissions vehicles is seen from 2030 onwards, it will occur only if cost reductions and enabling infrastructure are put in place for a rapid scale-up of ZEV trucks.

The prospects for electrifying trucking are improving. Even though China accounted for nearly 90% of electric heavy freight truck registrations in 2021, thanks to strong government support, global model availability is increasing (IEA, 2022b). Recent research suggests that, in Europe, electric trucking, in the form of battery EVs and electric road systems, could become competitive with conventional diesel trucks starting around 2030, with MFTs reaching cost parity a few years earlier than HFTs (ITF, 2022b). Rising diesel prices in India and globally (Figure 2.2) might provide additional interest in ZEV trucking technologies. Governments can help accelerate the deployment of electric trucks by introducing policies that will lower ZEV purchase costs. This includes bulk procurement, as done for buses, and early planning and investments in charging and grid infrastructure. The first step will be the successful implementation of pilot projects, to demonstrate smooth technical operation and to showcase benefits in terms of reduced noise and air pollution. Subsequently, roll out could be accelerated in applications with a high potential for electrification, such as deliveries in urban areas, municipal trucks (e.g., garbage trucks), vehicles used in ports or airports, or transport corridors with distances below 300 km, where overnight charging is possible at depots.

To reduce the upfront capital costs and encourage operators to pilot new electric technologies, India could consider bringing trucking into the FAME scheme. A bulk procurement programme for medium freight trucks similar to the one for electric buses of the CESL, deploying 5 450 electric MFTs instead of an equivalent fleet of diesel ICEs between 2023 and 2030, would save about 1 Mtoe of diesel and avoid 3 Mt CO_2 as well as more than 30 kt NO_X emissions over their average lifetime. Longer-range trucks will require high-power chargers that are currently expensive and would likely require grid upgrades. However, such investments could make sense for selected freight routes, e.g., for freight corridors that are currently being developed by MoRTH, for major freight interconnection points, or for corridors that are heavily used for both goods and passenger transport, providing charging opportunities for trucks and buses alike (MoRTH, 2022f).

Improved logistics can play a key role in limiting freight transport's fuel consumption by improving the on-road efficiency of truck operations and curbing overall growth in trucking activity. The government recently published the draft National Logistics Policy 2022, which provides an opportunity to both improve logistics efficiency and enable the deployment of low-carbon trucking technologies. Improving knowledge and data for the freight sector will be an important enabler to optimise and efficiently enable low-carbon trucking. Adequate origin-destination mapping and overall improved routing data are needed both to improve logistics efficiency and to identify the most suitable regions or routes for new technology adoption such as electric trucking. The draft National Logistics Plan provides an opportunity to collect and process the data needed and to kickstart the decarbonisation of the sector (NITI Aayog, RMI and RMI India, 2021, DPIIT, 2022).

Currently, hydrogen use in transport is limited to bus pilots that were started in New Delhi in 2020 (ICCT, 2022d). However, India's National Hydrogen Mission launched in August 2021 aims to scale up green hydrogen production and increase its use in different sectors, including transport. Hydrogen is seen as particularly well suited for heavy-duty vehicles that drive long distances. Like electric vehicles, hydrogen fuel cell vehicles produce no tailpipe emissions, but life-cycle emissions will depend on how the hydrogen is produced. India's National Hydrogen Mission aims to produce 5 Mt of "green" hydrogen each year by 2030, i.e., hydrogen produced through electrolysis of water, using renewable electricity (MoP, 2022c), an amount equal to one-third (600 PJ/14 Mtoe) of the energy requirements of India's truck fleet in 2021. Deployment of hydrogen fuel cell trucks will require targeted policy support, covering demand incentives and infrastructure investments. Such support mechanisms should specifically target vehicle categories in which large-scale application is most probable. Recent research suggests that fuel cell trucks might be more competitive for specific niche applications, rather than for the mass market, raising the question about the role of large-scale public investment in fuelling infrastructure (ITF, 2022).

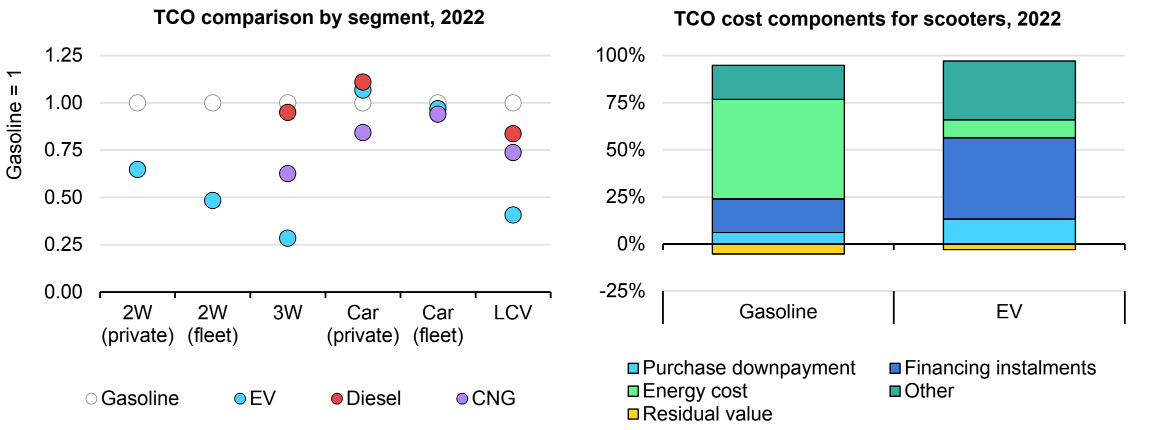
Improving the targeting of support policies for EV uptake

Electrification is a key pillar in India's strategy to decarbonise the road transport sector. It also brings direct benefits to air quality, especially in urban areas where exposure to exhaust emissions is high. India's two main policies to promote electrification, the FAME and PLI subsidies, have been important milestones to build trust in the technology. Even so, there is scope for India to further strengthen and accelerate its EV transition. In the APS, EVs could reach a sales share of nearly 50% by 2030, with considerable benefits in terms of CO_2 emissions and air pollutants, as outlined in Chapter 3.

In advanced economies, given the already high vehicle ownership, electrification strategies are focused on replacing the ICE vehicle fleet with EVs while encouraging a modal shift towards public transport and active mobility. India, by contrast, faces the dual challenge of improving access to mobility while promoting electrification. In practice, this means incentivising people who will purchase their first ever vehicle to opt for an EV. Bringing down the costs of EVs will therefore be critical. This section analyses the current and projected costs of battery EV and ICE vehicles in terms of the total cost of ownership (TCO), which considers both the purchase price and operating costs over a vehicle's life, to provide insights into where policy support could accelerate deployment.

The analysis shows that, except for privately-owned cars, EVs are already more competitive than equivalent ICE vehicle models in TCO terms (Figure 4.3). Highly utilised commercial vehicles, in particular electric three-wheelers, are most competitive, making a case for prioritising policy efforts on electrifying these vehicles. While the TCO is favourable, the purchase prices for EVs remain significantly higher than those for conventional vehicles across all vehicle categories. This translates into higher upfront costs and monthly instalments (Figure 4.3), constituting a barrier for EV uptake, particularly among middle and lower-income households and small businesses. Demand incentives that reduce the purchase price gap will therefore remain important. India should consider providing a purchase subsidy scheme such as FAME beyond 2024, when the scheme is set to expire, with a gradual phase-out by 2030 for vehicle categories in which EV models approach purchase price parity with conventional models. Tax benefits (e.g., the reduced GST, registration and road taxes) can help reach price parity earlier. To ensure they reach those that most need them, subsidies can be linked to income levels (as done in California). The current FAME subsidy already contains an equity element by restricting it to vehicles priced under INR 15 lakh (USD 20 190).

Figure 4.3 Total cost of ownership for different vehicle categories, 2022



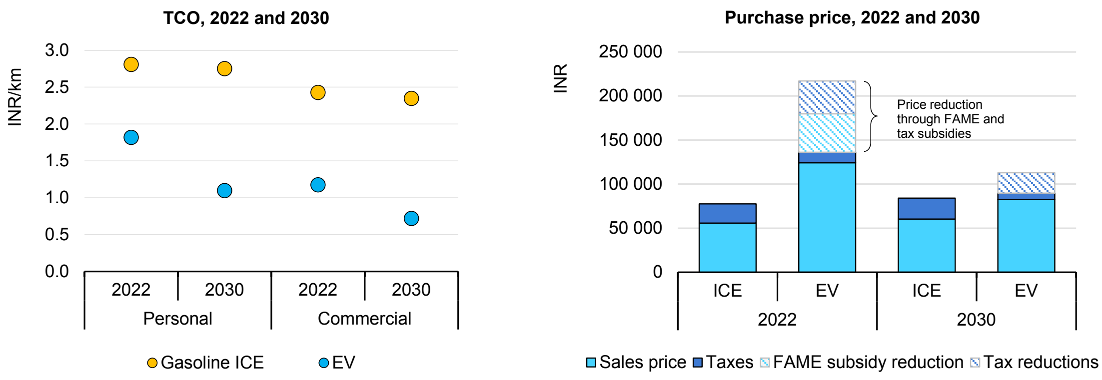
Note: LCVs = Light commercial vehicles. The TCO for three-wheelers (left panel) shows the cost for a passenger three-wheeler. A distinction is made between personal and fleet vehicles (vehicles used for delivery services or ride hailing) to account for the larger distances travelled by the latter per year. The cost breakdown (right panel) is based on the TCO of a personal scooter, assuming a lifetime of ten years and yearly running of about 12 000 km (see Annex B for details).

The need for policy support will vary by vehicle category. For cars, the upfront price difference is too large to be bridged by demand incentives alone, even in 2030. Here, regulatory policies will be important to push manufacturers to increase EV supply and reduce costs, for example through stringent fuel economy standards and ZEV sales requirements. Non-financial demand-side measures, such as preferential parking policies and low-emission zones, can provide additional incentives to consumers. For vehicle categories in which electrification is already price-competitive and well underway (e.g., three-wheelers), ambitious policy instruments such as ZEV sales requirements, fleet targets or restricting ICE commercial vehicle access within cities during the day, while giving EVs exemption to operate at any time (as attempted in Mumbai and Delhi) would be helpful. Such measures need to be accompanied by a rapid roll-out of charging infrastructure. As EV deployment scales up, a sound regulatory framework for battery management, enabling the establishment of a sustainable battery supply chain and material recycling will be necessary. Steps to strengthen battery end-of-life management have already been made (see Box 4.2).

Two-wheelers

The electrification of two-wheelers is in the early stages in India, but the market share is increasing, reaching 4% of new sales in 2022, compared to 1.1% in 2021 (MoRTH, 2022b). The higher uptake can be partly attributed to the increased demand incentive under FAME II (see Chapter 2), as well as greater availability of models for consumers to choose from. Despite this encouraging trend, the share of EV market sales is far from the combined share of nearly 60% for two- and three-wheelers in the APS in 2030, which is in line with India's net zero goal.

Figure 4.4 Cost comparison between a gasoline scooter and an equivalent electric scooter for total cost of ownership (left panel) and purchase cost (right panel), 2022 and 2030



Note: The TCO estimates for a personal two-wheeler assume a vehicle life of ten years and a yearly running of 11 000 km. For a commercial two-wheeler, they assume a vehicle life of five years and a yearly running of 33 000 km. The estimates assume that the FAME subsidy will expire in 2024. The purchase cost estimates (right panel) are shown for a personal scooter. Taxes include GST and Regional Transport Office (RTO) charges.

The TCO analysis reveals that electric two-wheelers are 40-50% cheaper than their gasoline-powered equivalent over their lifetime. Fuel cost savings pay back higher upfront costs within five years. In fleet applications (e.g., last-mile delivery services), electric models are more than 50% cheaper on a TCO basis; and the payback period would be under two years, reflecting the larger distances that commercially used two-wheelers drive every day. Current demand incentives considerably reduce upfront costs: In 2022, the sales price for electric scooters was about 3 times that of a comparable gasoline scooter. The FAME subsidy reduces this difference to 2.2 times more expensive, and favourable taxation to 2 times more expensive. Continuing a purchase subsidy scheme for two-wheelers beyond 2024 will therefore be important if price parity is to be achieved earlier than 2030 to accelerate adoption. In 2030, electric two-wheelers could approach purchase price parity even without the FAME subsidy, assuming that favourable taxation remains in place (Figure 4.4).

Three-wheelers

In 2022, India's electric three-wheeler sales reached 53% of new sales, compared to 41% in 2021 and 19% in 2019 (MoRTH, 2022b). The high market share is mainly due to favourable economics: on a TCO basis, electric three-wheelers are about 70% cheaper than their ICE-equivalent, and about half the cost of a CNG-powered three-wheeler[13] (Figure 4.3). Given that all three-wheelers are principally used in commercial applications in India, the TCO parity can be a significant inflexion point for electrification. In addition, the purchase price difference is smaller than in any other vehicle category. In 2022, the sales price of an electric three-wheeler was about twice the price of a gasoline equivalent; the FAME subsidy reduces the difference to 1.5 times and favourable taxation to 1.2 times. In our calculations, fuel savings can pay off this difference in less than two years. By 2030, sales prices for electric three-wheelers are projected to be equivalent to ICE models due to lower battery prices and technology maturity. It is expected that electric three-wheelers will become the dominant choice, even over CNG models.

Given the favourable economics, the three-wheeler fleet could be used to test new, ambitious policy instruments, including a gradual shift towards regulatory instruments such as EV supply requirements, a cap on the registrations for ICE three-wheelers in urban areas, and/or electrification targets for fleet operators. Such policies could be accompanied with measures that ease the difficulties associated with higher upfront costs. Demand incentives could be gradually phased down in 2025-2030, as the electric versions approach purchase price parity.

All of these measures can help create demand and provide scale benefits in terms of technology costs and maturity. A fleet mandate, proposed by the government of Delhi in a draft regulation of July 2022, requires companies running delivery and transportation businesses to electrify part of their vehicle fleet (covering two-, three- and four-wheelers). The regulation also establishes a licence fee differentiated by fuel consumption which exempts EVs, with revenue being channelled to the state EV fund (Government of NCT of Delhi, 2022).

Passenger cars

While the market share of electric passenger cars has steadily increased in the last two years, it remained below 1% in 2022 (MoRTH, 2022a). The low market share reflects the still relatively high costs of an EV for both personal and commercial uses (e.g., ride hailing), with respect to both upfront costs and the TCO. The sales price of an electric car is nearly 3 times as high as its gasoline-fuelled equivalent, and even with the FAME subsidy and favourable taxation, it is about twice that of a gasoline-fuelled car. Upfront price parity is expected to be achieved only after 2030, on the current technology curve and battery price trajectory.

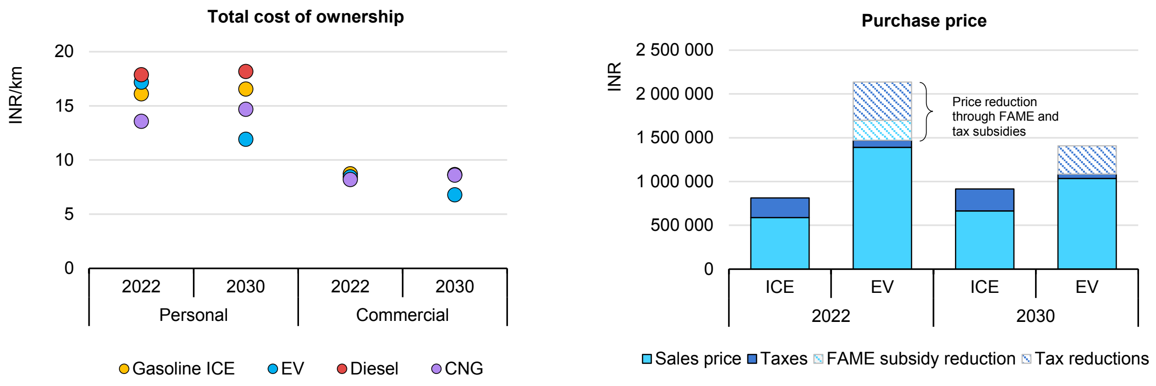
[13] Three-wheelers running on CNG form the second highest powertrain share in this category, contributing to nearly 30% of new sales in 2022.

In terms of TCO, an EV passenger car is nearly 10% more expensive than its gasoline-fuelled equivalent, and almost 30% more expensive than a CNG-fuelled equivalent (Figure 4.3). TCO parity with a gasoline equivalent is expected to be reached only around 2025, while by 2030 EVs will be clearly competitive on a TCO basis. In the case of ride-hailing vehicles for intra-city applications, EVs currently have a similar TCO to gasoline and CNG models and this is expected to remain so until 2025.

In the STEPS, the market sales share of electric cars reaches more than 10% in 2030 and more than 40% in 2050. To accelerate deployment, stringent fuel economy standards and other regulatory incentives could play an important role in increasing the supply of electric models, which remain constrained at present. In 2022, only three electric car models were eligible for the FAME subsidy, all supplied by one manufacturer, in comparison to two- and three-wheelers, where multiple models from several manufacturers are eligible (MHI, 2022b). There are benefits in prioritising an early transition of government-owned cars, commercial vehicles and company cars, which are likely to face fewer constraints in accessing capital. This would also help establish a secondary market for EVs, which in turn would make them available at an affordable cost for a much larger portion of the population.

Electrification of commercial applications (e.g., the ride-hailing market) could be accelerated through fleet targets or by capping ICE vehicle registrations. Some ride-hailing companies have already established internal electrification targets for their fleets: Uber for example aims to offer a 100% electric service in London, UK by 2025. The US state of California adopted a regulation in 2021 requiring the electrification of ride-hailing companies starting in 2023, and setting annual targets towards the goal to electrify 90% of passenger miles travelled by 2030 (CARB, 2022). While none of India's leading ride-hailing platforms has as yet committed to electrifying their fleets, the government of Delhi is pioneering electrification mandates, with its draft policy of July 2022 aiming to electrify 100% of four-wheeler ride-hailing fleets within five years from the policy notification (Government of NCT of Delhi, 2022).

Figure 4.5 Cost comparison between a gasoline-fuelled car and an electric car for total cost of ownership (left panel) and purchase costs (right panel), 2022 and 2030



Note: The TCO estimates for a personal car assume a vehicle life of ten years and a yearly running of 12 000 km. For commercial cars, they assume a vehicle life of five years and a yearly running of 52 000 km. The purchase price estimates (right panel) assume that the FAME subsidy will expire in 2024. Taxes include GST and RTO charges.

Light commercial vehicles

Electrification of the LCV market (i.e., vehicles less than 3.5 t) has been very limited so far, largely constrained by model availability and technology cost barriers. However, the Indian electric LCV market is now gaining momentum with leading manufacturers in the market launching models in 2022 and 2023.

Based on our TCO estimates, electric LCVs are already competitive compared to their ICE counterparts, with annualised costs per km roughly between 45% and 60% lower. The higher purchase costs of LCVs can be offset through fuel cost savings in less than two years. Given that LCV operators are usually small fleet owners of one to five vehicles, both the upfront price gap and the costs of financing will have to be reduced. At present, the sales price of electric LCVs is expected to remain nearly twice that of ICE variants up to 2025. The current FAME scheme is principally open for supporting electric LCVs, but in 2022, not a single model has been registered for subsidy eligibility (MHI, 2022a). With a demand subsidy of 20%, a reduced GST of 5% and a waiver of the Regional Transport Office (RTO) charges, the upfront cost differential could be nearly nullified. The design of focused incentives for LCVs within FAME, especially when combined with tax benefits and attractive financing conditions, could therefore considerably accelerate electrification. Subsidies could be limited to small businesses that face greater difficulties in accessing finance. For larger fleet operators, fleet transitions could be accelerated through electrification targets or even requirements.

Buses

India's public procurement of 5 450 electric buses in April 2022 is an innovative approach to the achievement of mass electrification. Experiences with the deployment of electric bus fleets have been positive so far, with cities such as Mumbai and Pune reporting less demanding maintenance and fewer breakdowns, in addition to a better driver and passenger experience (ICCT, 2022c). Following the successful tender, the Indian government aims to procure 55 000 additional electric buses in the next five years through demand aggregation. As for example in Chile, policies have successfully delivered the deployment of electric buses, making the capital Santiago home to the largest electric bus fleet outside of China. Policies there have been focused on stringent vehicle emissions standards, complemented by payment guarantees by local authorities for new buses incorporated into the city's fleet (ICCT and C40 Cities, 2020).

In India, 93% of the buses operating are privately owned (MoRTH, 2021b). Thus, providing a purchase subsidy, e.g., by extending the FAME scheme to private buses, and using demand aggregation for private bus operators to transition their fleets could help scale the electric bus transition. Further policy measures could include fleet mandates and fuel economy standards. With the recently proposed National Hydrogen Mission, pilot projects for fuel cell buses have begun, with the first indigenous fuel cell bus unveiled in Pune in August 2022 (MoST, 2022).[14]

Box 4.2 Boosting a circular economy in India's road transport transition

While it is widely recognised that EVs will play a critical role in India's clean transport transition, a massive scaling up of EVs may require navigating supply chain constraints for critical minerals, as well as new environmental risks, such as those related to mineral extraction and battery disposal. The transition to an electrified road transport system would ideally consider these risks and constraints.

Collecting, reusing and recycling batteries from EVs and hybrid vehicles is critical in managing the environmental impacts of battery production. Retired batteries still maintain value for mineral recovery and second-life applications, which in turn reduces the need to extract or import critical minerals. Recycled materials could meet between 5-20% of India's lithium-ion battery needs by 2030, depending on EV uptake and assuming that supply chain and circular economy strategies are widely in place. This will require effective end-of-life strategies and regulations for batteries.

[14] Due to lack of data, this report contains no TCO analysis for buses.

India's adoption in August 2022 of the Battery Waste Management Rules was an important step. The rules, based on the concept of Extended Producer Responsibility (EPR), require battery producers and importers to collect and recycle or refurbish waste batteries (including EV as well as portable, automotive and industrial batteries). The legislation specifies procedures for end-of-life battery collection, transport, refurbishing and recycling and disposal, and sets minimum recovery targets starting in 2025. It also provides for a trading mechanism of EPR certificates, creating a potential market mechanism for compliance. The rules also require producers to meet minimum use of recycled materials (as a percentage of total dry battery weight) in new battery production starting from 2025.

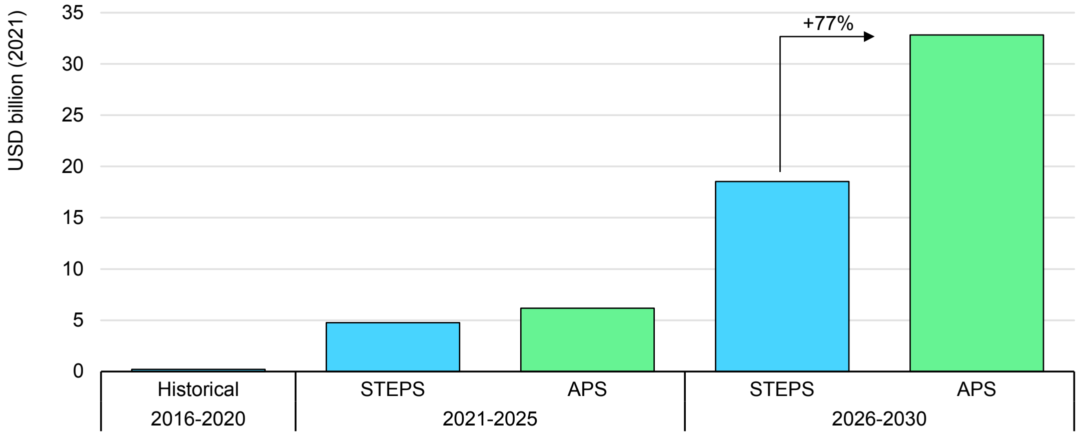
The recently launched scrappage policy (see Chapter 2) provides the opportunity to strengthen the circular economy approach in the automotive industry, provided that scrappage and recycling centres can be established rapidly and at scale. The recycling of end-of-life vehicles can help reuse critical resources such as steel, plastic and copper, reducing raw material costs by up to 40% if all reusable materials are recovered. However, the recovery rates in India are currently estimated at 70-75%, compared to global benchmarks of 85-95%, in part due to a largely informal and fragmented scrapping/recycling sector.

Sources: MoEFCC (2022b), MoRTH (2021c), RMI and RMI India (2022), The Economic Times (2021).

Strengthening electric vehicle financing

Achieving large-scale electrification in India will require considerable mobilisation of capital and finance towards EVs and related infrastructure. Average annual investments in EVs and private chargers stood at about USD 21 million in 2016-2020, but would need to increase to USD 19-33 billion in 2026-2030, depending on the scenario (Figure 4.6) Cumulatively, these investments amount to around USD 120 billion in the STEPS, or close to USD 200 billion in the APS over the decade to 2030. National estimates of cumulative investment needs for vehicles, charging infrastructure and batteries point to even higher investment needs of USD 200 to 270 billion over the coming decade (CEEW, 2020; RMI, 2021).

Figure 4.6 Average annual investment in EVs and private chargers in India in the STEPS and APS, 2015-2020 to 2025-2030



India's flagship EV initiatives, the FAME II and the PLI schemes, provide incentives that together amount to more than USD 7 billion. These are complemented by further investments and incentives at central and state levels, some of which are presented in Chapter 2. On the private sector side, several of the largest vehicle manufacturers have announced significant investments in EVs (The Economic Times, 2022e, Thakkar and Shyam, 2022). and EV start-ups raised nearly INR 4 500 crore (USD 605 million) in venture capital between 2014 and 2019 alone (NITI Aayog and RMI India, 2021). Innovative business models for mobility services, including ride-hailing and rental services, battery swapping and vehicle financing are also on the rise.

Most vehicle sales in India involve vehicle financing, including through banks and non-banking financial corporations (NBFCs), but also leasing providers, fintech start-ups and others. Commercial vehicles, as well as two- and three-wheelers, are leading in electric vehicle financing (CEEW, 2022a). The current vehicle retail finance industry is estimated at USD 60 billion, while the annual EV loan market size alone could reach INR 3.7 lakh crore (USD 50 billion) in 2030, over 80% of the current total (NITI Aayog, RMI and RMI India, 2022).

Main financing challenges

Major challenges of EV financing can be grouped around three broad areas: i) lack of regulatory certainty and co-ordination in the sector; ii) a high risk-perception of financiers regarding both asset and business model risks and limited risk mitigation mechanisms tailored to the EV market; and iii) limited availability and uptake of targeted financing mechanisms.

The lack of an overarching vision or targets for EV sales, coupled with uncertainty over the continuation of current subsidies, might affect profit margins for manufacturers and affordability for end-users and thereby contribute to investment uncertainty. Financiers have also criticised the multitude of public institutions with responsibilities for EV policies in India, a multiplicity which creates challenges for designing effective financing solutions.

Financiers in the EV space still have a widespread perception of high asset and business model risks, which is mainly related to uncertainty over vehicle technology, battery performance and battery life, and the resale value of EVs in cases of borrower default. Hedging against the occurrence of such risks drives up the cost of capital and creates access hurdles to the required funding. Additional challenges for consumers include higher insurance rates compared to ICE vehicles, which are based on the higher sales prices of EVs, relatively low loan-to-value ratios and short loan tenures that increase the equated monthly instalments, which are particularly challenging for cash-based borrowers (EVreporter, 2022; NITI Aayog and RMI, 2021). Mechanisms to reduce the perceived and/or real risks of EV financing are rarely employed in India.

The availability of customised financial products for EVs is still limited. EV financing models range from equity investment, personal, corporate or retail loans, to demand aggregation and bulk procurement, as well as models separating battery and vehicle financing. The State Bank of India's Green Car Loan remains the leading financing product for electric passenger cars, offering discounted interest rates, extending loan tenure up to eight years and offering a loan-to-value ratio up to 90% (SBI, 2022). Several banks provide special loans for electric three-wheelers, but uptake remains low due to the relatively unstructured market and a largely cash-based borrower profile that do not meet credit and income statement requirements. Several NBFCs and fintech companies like Revfin in Delhi and Three Wheels United based in Bangalore offer digital lending models that reduce transaction costs and improve access to financing for these cash-based customers that are often excluded from traditional lending models. Nonetheless, particularly smaller and non-captive[15] NBFCs require access to low-cost financing from larger banks to ensure liquidity in the medium to long term.

Options to strengthen EV financing

There are several actions available to overcome barriers and strengthen EV financing, summarised in Table 4.1.

[15] The Reserve Bank of India defines a captive NBFC as one that holds receivables generated on account of the parent company's activities at least at 90% of its total assets. Captive NBFCs have partnered with vehicle manufacturers to provide specific finance conditions to consumers.

Table 4.1 Instruments to improve EV financing in India

Instrument	Barriers addressed	Outcomes	Key stakeholders
Priority sector lending inclusion	Access to capital, high cost of capital	Improved access and lower cost of capital	Central government, RBI and other FIs
Subsidy scheme continuation	High upfront investment, policy uncertainty	Lower upfront investment	Central and state governments
Interest Rate Subsidies	High cost of capital	Lower interest rates, lower cost of capital	Central and state governments
Risk-sharing facilities	Technology, business model and customer risk	Improved access and lower cost of capital	Central and state governments, Development banks and other FIs
(Partial) credit/loan guarantees	Technology, customer and utilisation risk	Improved access and lower cost of capital, longer loan tenure	Central and state governments, fleet operators, FIs
Utilisation guarantees	Technology, customer and utilisation risk	Improved access to capital	Fleet operators, FIs
Extended product warranties and guarantees;	Technology risk, manufacturer risk	Lower cost of capital	OEMs, FIs
Business model innovation	High upfront investment, technology risk, lack of performance data, customer risk	No/lower initial investment; economies of scale (lower unit and transaction costs); lower cost of capital	OEMs, FIs, private sector, utilities
Policies promoting a secondary EV and battery market development	Resale risk, lack of performance data, customer risk	Lower cost of capital	Central and state governments, OEMs, FIs
Improved sector co-ordination, data availability and capacity enhancement	Limited capacities of FIs, lack of performance data, high cost of capital	Economies of scale (lower unit and transaction costs); improved access and lower cost of capital	Central and state governments, FIs, international partners

Note: RBI stands for Reserve Bank of India, OEMs stands for Original Equipment Manufacturers and FIs stands for financial institutions.

First, India could include certain EV categories in the priority sector lending guidelines of the Reserve Bank of India (RBI). These guidelines mandate scheduled commercial banks[16] to allocate 40% of net bank credit to priority sectors with high employment and poverty alleviation potential but low bankability. In addition to signalling the government's commitment to vehicle electrification, this could institutionalise EVs as an asset class in India's financial system, incentivise

[16] Scheduled commercial banks are those included in the second schedule of the RBI Act 1934 and which carry out regular banking business like accepting deposits, providing demand withdrawal facilities etc. Based on the fulfilment of certain criteria as scheduled banks, they are authorised to borrow funds from the RBI.

banks to expand EV lending, and allow NBFCs to access lower-cost capital and create co-lending models with banks (NITI Aayog, RMI and RMI India, 2022).

Continuation of subsidy schemes such as FAME II and PLI remains important to reduce the purchase price gap between conventional and electric vehicles, to enhance both investor and consumer trust in the technology and therefore improve financing conditions for EVs. Including swappable batteries and vehicles sold without batteries in FAME could help accelerate implementation of India's draft battery swapping policy.

Interest rate subsidies, currently offered by only two states, offer a percentage subsidy on commercially offered interest rates, thereby reducing the cost of capital and raising loan affordability. The Delhi Finance Corporation, for example, offers a 5% interest rate subsidy on loans for e-autos and e-carriers, while the Kerala Finance Corporation offers a 3% subsidy across all categories. Based on the TCO analysis conducted for this report, a 5% interest rate subsidy, such as the one provided in Delhi, would lower the TCO for electric LCVs by almost 7%. The TCO of electric three-wheelers (both passenger and cargo) would be reduced by nearly 5% and that of electric two-wheelers by 2.5%. Longer loan tenures would increase the average TCO in all cases considered, owing to the higher overall amount of interest paid over the loan tenure but would remain below that of comparable conventional vehicles.

Risk mitigation instruments can take several forms. Multilateral financial institutions and bilateral development banks could partner with the central government and/or other financiers to offer blended finance, create dedicated credit lines with preferential financing terms, first loss facilities or credit guarantees, as well as technical assistance services. Such risk mitigation mechanisms can cover general default or the realisation of specific risks, thereby allowing banks and NBFCs to offer better financing conditions with lower interest rates and longer loan tenures. A successful example for such a mechanism, the Partial Risk Sharing Facility for energy efficiency, established in 2015, provides partial default risk coverage to 14 partner financial institutions in providing loans to specific energy efficiency investments. A similar facility with first loss guarantees could be created for EV loans.

Risk mitigation mechanisms can also be provided by private sector stakeholders. Fleet operators and last-mile delivery companies can provide partial credit guarantees for their driver partners to lenders, and give utilisation guarantees to driver partners, thereby distributing default risks and increasing their access to financing. In addition, some manufacturers already provide product guarantees and extended warranties for electric three-wheelers and cars, which help mitigate technology risks, build consumer and financier confidence, and ultimately contribute to creating a secondary market for electric vehicles (NITI Aayog and RMI, 2021).

Innovative business models can help mitigate risks by reducing upfront investment needs or providing access to financing. The bulk procurement of electric buses under FAME II is based on a Gross Cost Contract (GCC), a leasing model that mitigates risk. Under this model, a service provider is contracted to supply and operate electric buses for a defined period and is paid based on a fixed cost per kilometre with a "minimum guaranteed run", i.e., a defined minimum of kilometres per day, to mitigate the utilisation or ridership risk. State Transport Authorities thereby do not have to make upfront investments, are not exposed to the performance risk of the buses, and benefit from lower TCOs compared to conventional buses. Given the weak financial status of many state transport undertakings, leasing models like the GCC could be replicated and expanded. Expanding and promoting business models and digital lending solutions for customers with cash-based incomes and no or low credit history, would also help in overcoming the access barrier.

Initiatives to finance batteries separately from the vehicle aim to decouple battery costs from the vehicle, thereby reducing the upfront investment for vehicle owners. Battery swapping and plug-in charging models separate battery usage from charging. This has the potential to improve battery management and co-ordinate charging and can accelerate the creation of business models that use aggregated batteries to provide grid services. Battery swapping, battery leasing and Battery-as-a-Service business models are particularly interesting for electric two- and three-wheelers and LCVs, due to their lower space and infrastructure requirements, and should be further explored. In April 2022, NITI Aayog released a draft battery swapping policy for two- and three-wheelers, which stipulates minimum technical and operational requirements for battery swapping ecosystems. Battery safety and reliability are key for the success of battery swapping models. Discussions on the creation of standards and parameters for battery safety, quality and performance as well as interoperability have started. Based on the TCO analysis conducted for this report, electric two-wheelers with swappable batteries in vehicle fleets significantly lower the financing burden. Despite the higher TCO compared to non-swappable electric two-wheelers, their TCO remains around 2% below conventional ones.

FAME II subsidies are currently not applicable for electric two-wheelers without pre-fitted batteries, but three states (Delhi, Maharashtra and Goa) offer purchase subsidies. Some states also offer incentives for setting up battery swapping stations. Clear policies for used battery collection, repurposing and recycling to create a circular economy for EV batteries would help grow the EV ecosystem. Battery repurposing programmes can further contribute to creating a secondary market for vehicle batteries.

Creating an EV data repository (including vehicle specifications, long-term vehicle and battery performance and operating costs) could also contribute to reducing technology risk perception, building a secondary market for used vehicles and thereby establishing a resale value of EVs – which is important for financiers in case the borrower defaults on payments. The government's e-Amrit platform already contains information on important aspects of the e-mobility transition and could be further expanded.

Adopting actions to reduce air pollution

To address the poor air quality in India's urban areas, in 2019 the MoEFCC launched the National Clean Air Programme (NCAP) which aims to reduce PM concentration levels by 35-50% by 2026 relative to 2017 levels in India's most polluted cities. The actions to reduce air pollution span all levels of government and include the further strengthening of emissions standards, rapid phase-out of the oldest, most polluting vehicles, and traffic management. Policies that reduce CO_2 emissions or fossil fuel consumption (e.g., EV support and fuel efficiency promotion) are also included, given their significant co-benefits for urban air pollution.

Strengthening emissions standards

At the national level, the leapfrogging to BS-VI has played an important role in reducing air pollutants from vehicles. The next stage of standards can further improve air quality. Over the past two decades, India has followed Europe's standards. In November 2022, Euro 7/VII standards (for cars and trucks, respectively) were proposed for the EU and UK, with an anticipated implementation in 2025 for LDVs and 2027 for HDVs. The proposed standards include: the update and tightening of limits for pollutant emissions as well as coverage of additional pollutants; new testing requirements; regulation of the durability of batteries in electric vehicles; and longer compliance with the rules. In a global first, the standards set limits for particulate non-exhaust emissions from brakes and tyres.

For India, a time lag of several years is anticipated as being necessary to give industry sufficient lead time. Assuming that Euro 7/VII norms are implemented by 2025 and 2027, India could thus consider implementing updated Bharat standards in the early 2030s.

Furthermore, India is expected to move in April 2023 to Real-Driving Emissions (RDE) testing. This procedure measures a vehicle's emissions under on-road driving conditions through portable emissions measurement systems that collect data to verify regulatory limits under BS-VI standards. Consequently, testing results based on a RDE procedure are not only affected by fuel composition and powertrain technologies but also by ambient temperature, altitude, humidity, road conditions and vehicle load. Therefore, it is crucial that India adjusts existing RDE tests to national geographical and meteorological conditions and take driving conditions into account (IIT Kanpur, 2021).

Accelerating fleet renewal

India's recently introduced scrappage policy could play an important complementary role in reducing air pollution, by encouraging the retirement of the oldest, most polluting vehicles. The policy requires passenger cars older than 20 years and commercial vehicles older than 15 years to pass a "fitness test" to keep their registration (see Chapter 2). The scrappage of older commercial vehicles is of particular importance, as these diesel-fuelled vehicles, typically manufactured before 2000, account for a disproportionate amount of air pollutant emissions. Around 12% of commercial vehicles are older than 15 years old, but existing data suggest only a small proportion are more than 20 years old (CSE, 2020b). India's fleet of freight trucks accounted for 60% of India's NO_X and 60% of its exhaust-related $PM_{2.5}$ from road transport in 2021, while passenger cars accounted for around 10% and 15%, respectively.

The impact of the scrappage policies depends on a range of parameters: emissions avoidance increases with the number and age of vehicles retired as well as with the stringency of the air pollutant emissions standards of the vehicles used to replace the mobility needs of the scrapped ones. India's secondary vehicle market is sizeable, and it is likely that scrapped vehicles are replaced with new vehicles that are not compliant with latest BS-VI emission standards. If India's scrappage policy were to be implemented in the next two years, the replacement of an important share of end-of-life freight trucks could avoid over 200 kt NO_X and up to 10 kt $PM_{2.5}$ emissions annually (approximately 17% of NO_X and 11% of $PM_{2.5}$ emissions from trucks in 2025), depending on the assumptions about the retirement rate of trucks older than 15 years and assuming that scrapped vehicles are replaced with new trucks that meet BS-VI standards. If they were to be substituted with trucks that meet air emissions standards equivalent to BS-IV, emissions avoidance would be substantially lower, around 65 kt NO_X and 8 kt $PM_{2.5}$. Similarly, the scrapping of a substantial share of passenger cars older than 20 years could result in the avoidance of up to 12 kt NO_X, if replaced with BS-VI vehicles and up to 8 kt NO_X, if substituted with BS-IV vehicles, and less than 2 kt $PM_{2.5}$ in both cases.

To help ensure that scrapped vehicles are replaced with new, efficient ones, financial incentives will be key. While a range of incentives exist, their cumulative financial benefit is limited when compared with the cost of a new vehicle. Difficulties in accessing credit for new vehicle purchases, especially by smaller operators, can also impede change. Here, opportunities for aggregation and guarantors can play important roles (ICCT, 2021g; IEA and EPE, 2021). To realise the full benefits of the vehicle scrappage policy the following action can be considered:

- Understand and capture the characteristics of the vehicles being retired, including at the state level. Data collection and reporting procedures should therefore be delineated from the outset.
- Consider the introduction of state level goals and targets for retirements.
- Take steps to ensure that the oldest and most polluting vehicles are removed. This can include the requirement for multiple inspection and maintenance tests as well as complementary measures at the state or city level, e.g., in terms of age restrictions. In Mexico and in key regions in China, for example, older commercial heavy vehicles are required to be tested two to four times each year (ICCT, 2021g).
- Align incentives to facilitate the achievement of policy goals. This can include increased fiscal support for the removal of older commercial vehicles as well as action relating to the adoption of EVs.
- Ensure financial barriers to new vehicle purchases are addressed, especially for smaller operators where they can be highest. These can include the role of aggregation to reduce costs as well as the use of risk sharing mechanisms.
- Consider reducing the age limits of vehicles subject to testing and scrappage.

Local action to reduce air pollution

Under the NCAP, non-attainment cities are required to develop City Clean Air Plans that list sector-specific interventions with pre-determined timelines. Measures identified in these plans include implementation of BS standards and the phase-out of older vehicles, expansion of public transport, transition to clean fuels, in particular electrification, congestion control and regulation of road freight transport. Odisha, for example, proposed among other measures to increase its bus fleet and improve its reliability, to implement a state-level EV policy and to ban diesel-fuelled -three-wheelers and improve trucking logistics, e.g. through the development of a diversion plan for entry of non-destined trucks into the respective cities (SPCB Odisha, 2019). The City Clean Air Plans can be a powerful tool to tackle air pollution from road transport, provided that local authorities are equipped with sufficient capacity and resources to design and fully implement these plans.

Access restrictions for the most polluting vehicles, including those above a certain age, and the establishment of low-emission zones can bring additional air quality benefits. Internationally, among the most prominent examples is London's Ultra Low Emission Zone (ULEZ), first implemented in Central London in 2019 and to be expanded to cover the entire city in 2023. Vehicles passing through the zone must comply with its emissions standards to avoid a daily fee, paid in addition to the city's congestion charge. Delhi has banned diesel vehicles older than ten years and gasoline vehicles older than 15 years. More information is however needed to understand where these vehicles are subsequently used, to help ensure that pollution challenges are not simply transferred elsewhere. City level action can also facilitate monitoring, for example through coloured badges which act as certificates for passing fitness tests. Finally, moving freight deliveries to off-peak hours can help reduce congestion and urban air pollution; India's Freight Smart Cities plan, launched in July 2021, aims at enhancing urban freight efficiency and reducing logistics costs (DoC, RMI and RMI India, 2021).

Step up international collaboration and engagement efforts

International collaboration on road transport decarbonisation is less extensive than in other sectors but is more advanced than several other sectors at earlier stages of their transitions, such as steel. Governments exchange best practices on road transport ZEV policy in several initiatives, including through the Zero-Emission Vehicle Transition Council and its International Assistance Taskforce, the Global EV Advisory Council, the International Zero Emission Vehicle Alliance, and the Climate Group's EV100 initiative. There are also several important international conferences where governments work together on transport issues, including the OECD's International Transport Forum and the annual China EV100 Forum.

India has joined and benefitted from a number of initiatives such as the Clean Energy Ministerial's Electric Vehicle Initiative, the Climate Group (EV100), Zero Emission Vehicle Transition Council (ZEVTC) International Assistance Taskforce and the First Movers Coalition. International collaboration is needed in a number of areas if the world is to speed up the energy transition in the road transport sector while at the same time reducing costs. Governments could, for example, co-operate on the development of a timeline by which all new road vehicle sales should be zero emission or agree a common understanding of the technologies that are consistent with the goal of zero-emissions road transport. Governments should work together and with industry to avoid further divergence of standards for charging infrastructure. As both a producer and importer of EVs and with an industry at a nicest stage in terms of development of infrastructure to support EVs, India has much to gain and share from a higher level of international collaboration. The is a large opportunity is for India, its businesses, communities and citizens to work together with global partners to accelerate the growth of markets for clean technologies and sustainable solutions while continuing to compete to supply them.

Annexes

Annex A Classification of vehicle categories

Table A.1 Classification of vehicle categories

Category		Definition
2/3-wheelers	Two- and three-wheelers	Fleet of mopeds, motorcycles and motorised three-wheelers, with two-wheelers accounting for the vast majority
PLDVs	Passenger light-duty vehicles	-/-
Buses	Buses	-/-
LCVs	Light commercial vehicles	Four-wheelers with a GVW of below 3.5 t
MFTs	Medium freight trucks	Vehicles with a GVW between 3.5 t and 12 t
HFTs	Heavy freight trucks	Vehicles with a GVW of more than 12 t
LDVs	Light-duty vehicles	Aggregated fleet of PLDVs and LCVs
HDVs	Heavy-duty vehicles	Aggregated fleet of buses, MFTs and HFTs

Notes: GVW stands for gross vehicle weight.

Annex B Total cost of ownership analysis

Most emissions reductions in India's road transport sector are likely to come from powertrain switching, dominated by electrification. Of the various drivers of EV adoption, understanding the economic viability of EVs compared to their ICE counterparts becomes important to help understand most economic use cases and to design effective policies. One such measure is the total cost of ownership (TCO), which estimates the cost per unit distance over the operating life of the vehicle across different powertrains.

Four automotive categories were analysed in this report using the TCO tool:

- Two-wheelers: Personal and service applications (e.g., for last-mile delivery)
- Three-wheelers: Passenger and cargo applications
- Passenger cars: personal and intra-city service applications (e.g., ride-hailing)
- Light commercial vehicles: commercial applications (GVW less than 3.5t).

The TCO tool is estimated for different vehicle categories assuming purchase in 2022, 2025 and 2030, to provide insights on TCO and price parity evolution over the next decade. It is important to note that while the TCO estimate is a good indicator of the economic viability of an EV over its operating life cycle, the actual adoption will also depend on the upfront price gap between the EV and ICE variant. Thus, while TCO parity is a key indicator of the effects of demand-incentive policy measures, price parity is a key indicator of technology maturity. TCO parity is a necessary but insufficient condition for EV adoption.

Assumptions about the vehicle lifetime and annual running are provided below the respective summary table. All calculations assume that FAME II will not be expanded beyond 2024, but that tax incentives (i.e., a GST of 5% and a waiver/ reduction for the road and registration tax) remain in place until 2030. The assumptions pertaining to fuel price developments are based on the IEA's World Energy Outlook. Battery capacity is assumed to increase for 2025 and 2030. It should be noted that smaller (larger) capacity could reduce (increase) the vehicle's TCO.

Table B.1 TCO estimates for two-wheelers (INR/km)

Vehicle type		2022		2025		2030	
		Personal	Commercial	Personal	Commercial	Personal	Commercial
Scooter	Gasoline	2.81	2.43	2.78	2.40	2.75	2.35
	BEV	1.82	1.17	1.58	1.04	1.10	0.72
Motorcycle	Gasoline	3.00	2.51	2.99	2.48	2.98	2.45
	BEV	1.62	1.14	1.39	0.98	1.01	0.73

Note: Personal two-wheelers are assumed to have a lifetime of ten years and yearly running of about 12 000 km. Commercial two-wheelers are assumed to have a lifetime of five years and yearly running of about 36 000 km.

Table B.2 TCO estimates for three-wheelers (INR/km)

Vehicle type	2022		2025		2030	
	Personal	Commercial	Personal	Commercial	Personal	Commercial
Gasoline	5.54	5.36	5.48	5.30	5.37	5.20
Diesel	5.26	5.19	5.10	5.01	5.03	4.92
CNG	3.47	-	3.50	-	3.56	-
LPG	3.78	-	3.80	-	3.84	-
BEV	1.58	1.53	1.81	1.61	1.16	1.08

Note: Both passenger and cargo three-wheelers are assumed to have a lifetime of ten years. Annual running is assumed to be 32 000 km and 36 000 km, respectively.

Table B.3 TCO estimates for passenger cars (INR/km)

Vehicle type	2022		2025		2030	
	Personal	Commercial	Personal	Commercial	Personal	Commercial
Gasoline	16.10	8.71	16.40	8.64	16.55	8.65
Diesel	17.87	-	17.91	-	18.18	-
CNG	13.57	8.19	13.98	8.33	14.68	8.59
BEV	17.18	8.44	16.23	8.35	11.90	6.79

Note: Personal cars are assumed to have a lifetime of ten years and yearly running of about 12 000 km. Cars used in fleet applications for ride hailing are assumed to have a lifetime of five years and yearly running of about 52 000 km.

Table B.4 TCO estimates for light commercial vehicles (INR/km)

Vehicle type	2022	2025	2030
Gasoline	8.48	8.36	8.16
Diesel	7.10	6.89	6.67
CNG	6.25	6.16	6.07
BEV	3.46	3.29	2.31

Note: Light commercial vehicles are assumed to have a lifetime of ten years and yearly running of about 43 000 km.

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Abbreviations and acronyms

APS	Announced Pledges Scenario
BEE	Bureau of Energy Efficiency
BEV	Battery electric vehicle
BS	Bharat Stage emission standards
CAFE	Corporate Average Fuel Economy
CESL	Convergence Energy Services Limited
CO_2	carbon dioxide
CNG	Compressed Natural Gas
EESL	Energy Efficiency Services Limited
EU	European Union
EV	Electric vehicle
FAME	Faster Adoption and Manufacturing of Electric Vehicles programme
GHGs	Greenhouse gases
GST	Goods and services
GVW	Gross vehicle weight
HDV	Heavy-duty vehicle
HFTs	Heavy freight trucks
IEA	International Energy Agency
IIASA	International Institute of Applied Systems Analysis
LCV	Light commercial vehicle
Lde	Litres of diesel equivalent
LDV	Light-duty vehicle
Lge	Litres of gasoline equivalent
MFTs	Medium freight trucks
MHI	Ministry of Heavy Industry
MoP	Ministry of Power
MoRTH	Ministry of Road Transport and Highways
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
NAPCC	National Action Plan on Climate Change
NBFCs	Non-banking financial corporations
NCAP	National Clean Air Programme
NEMMP	National Electric Mobility Mission Plan
NO_X	Nitrogen oxides
NDC	Nationally Determined Contribution
PHEV	Plug-in hybrid electric vehicle
PLDV	Passenger light-duty vehicle
PLI	Production-Linked Incentive scheme
$PM_{2.5}$	Fine particulate matter
R&D	Research and development
RBI	Reserve Bank of India
RTO	Regional Transport Office

SO_2	Sulphur dioxide
STEPS	Stated Policies Scenario
t	Tonnes
TCO	Total cost of ownership
UK	United Kingdom
US	United States
VAT	Value-added tax
Vkm	vehicle kilometres
WEO	World Energy Outlook
WLTP	Worldwide Harmonised Light Vehicles Test Procedure
ZEVs	Zero-emission vehicles
ZLEVs	Zero and low-emission vehicles

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