Implementing Clean Energy Transitions

Focus on road transport in emerging economies

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Abstract

This report assesses the impact of the road transport sector on energy demand, CO_2 emissions and air pollution in several selected major emerging economies over the coming decades under several IEA modelling scenarios. Most notably the Announced Pledges Scenario (APS) aims to show to what extent announced ambitions and targets, including the most recent ones, are on the path to deliver emissions reductions required to achieve net zero emissions by 2050.

Bringing about a road transport decarbonisation pathway in line with the APS in the selected major emerging economies - Brazil, People's Republic of China, India, Indonesia, Mexico and South Africa - will require significant enhancement of existing policies and the introduction of new innovative policies and measures in each of selected countries. Our report sets out six policy areas critical to the achievement of the road transport transitions and a series of recommendations for strengthening financing for the sector.

Importantly, the report provides detailed reference to a wide range of policy measures and good practice already in place in many major emerging economies elsewhere to facilitate knowledge sharing among countries. It also places a special emphasis on the road transport sectors of India and Indonesia. These countries are IEA partners in their respective regions and benefit from an enhanced programme of work.

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Table of contents

List of figures

List of boxes

List of tables

Executive summary

The road transport sector is a cornerstone of robust economic development. It accounted for around 20% of global final energy consumption and about 50% of oil demand in 2021, a similar share to 2000, despite rising demand for transport services. Factors such as transport activity, shifts between transport modes, energy efficiency, and the carbon content of fuels shape energy demand and CO_2 emissions and pollution from the sector. As populations and incomes grow across a wider range of countries, demand for transport services is projected to rise, along with the need to decarbonise.

One of the objectives of this report is to broaden understanding of where the road transport sector is heading in major emerging economies, particularly in light of recent net zero pledges. The major emerging economies analysed in this report – Brazil, People's Republic of China, India, Indonesia, Mexico and South Africa – represented around 14% of global road transport energy demand in 2000; by 2021, this share was 27%. Their total vehicle stock was around 185 million in 2000; at end-2021 it was about one billion, a fivefold increase. This compares to an increase of around 40% in the rest of the world over the same period.

Total road transport fuel consumption in these emerging economies is projected to rise to 725 million tonnes of oil equivalent (Mtoe) by 2050 in the IEA's Stated Policies Scenario (STEPS), with fossil fuel use peaking around 2030 and declining thereafter. By contrast, in the Announced Pledges Scenario (APS), fuel consumption in the road transport sector in major emerging economies peaks at around 660 Mtoe by the end of this decade. Fuel economy improvements, along with greater electricity use, and to a much lesser extent hydrogen use, sees fuel consumption decline to 500 Mtoe by 2050, despite rising vehicle fleet numbers. Electricity accounts for more than 40% of transport energy consumption as the electric vehicles fleet expands, highlighting the importance of decarbonising generation and modernising electricity grids.

Global CO_2 emissions in the road transport sector increased by almost 40% between 2000 and 2021 to almost 6 Gt CO_2. Greater emissions from light-duty vehicles and trucks in the selected emerging economies accounted for around 60% of this increase, with India and China making up for the largest share. In these countries, direct CO_2 emissions from the road transport sector reached more than 1.5 Gt CO_2 in 2021 and continue to rise until mid-2030 to a peak of around 1.8 Gt CO_2 in the STEPS, decreasing thereafter to 1.6 Gt CO_2.[1] In India and

[1] All CO_2 numbers quoted in this report are direct CO_2 emissions except where otherwise stated.

Brazil, emissions decrease only after 2040, while other countries either see their road transport-related emissions stabilising closer to 2050, in the case of Indonesia, or continuing to rise, in the cases of Mexico and South Africa. In contrast, in the APS, emissions from road transport in the selected emerging economies peak by the mid-2020s and drop to less than 0.6 Gt CO_2 by 2050. Two-thirds of this decrease comes from China and India, which aim to achieve carbon neutrality before or by 2060 and 2070 respectively.

The ambitious policies in the APS could generate around 13 Gt CO_2 in cumulative emissions savings in the road transport sector. In the APS, at least 70% of the total car stock is electric in all major emerging economies by 2050, except for Brazil with its greater share of biofuels-powered vehicles. Direct emissions from cars in selected major emerging economies could drop to 140 Mt CO_2 by 2050, down about 80% from 2021.

The road freight sector faces more difficulty decarbonising. Not only will economic expansion and population growth boost demand for goods transport, but electric or fuel cell options are not always available or cost-effective. In both IEA scenarios, emissions from trucks are projected to continue upwards until the end of this decade. In the APS, however, the major emerging economies see a fall from 565 Mt CO_2 in 2021 to 400 Mt CO_2 in 2050. Even in this more ambitious pathway, trucks remain by far the largest emitter in the transport sector.

Governments play a vital role in leading clean energy transitions in the road transport sector. Major emerging economies have an opportunity to leap-frog outdated existing road transport models by implementing specific transport policy interventions, by bringing greater clarity to the policy decision-making process and by empowering implementing agencies.

The investment and finance challenge

In the STEPS, average annual end-use investment in road transport needs to reach USD 110 billion in the second half of the 2020s with an additional 40% needed annually through 2050. In the APS, annual investment will need to reach USD 150 billion between 2026 and 2030, rising to over USD 230 billion in the period to 2050. This expansion requires substantial national efforts to improve the environment for clean energy investment, as well as international efforts to increase availability of capital for low-carbon mobility in emerging economies.

Most of the investment in the APS occurs in China, but investment is set to grow more rapidly in other major emerging economies, notably in India and Indonesia. Annual spending on EVs in the major emerging economies needs to increase to USD 90 billion in 2026-2030 in the APS, and planned policies – if fully implemented – would deliver 80% of this investment. A wider gap exists in energy efficiency spending, which needs to double towards 2030 in the APS, but looks set to remain at current levels without further policy efforts. In the long term, spending on electrification is set to account for an increasingly larger share of investment in road transport, while investment in energy efficiency declines in the APS as conventional internal combustion engine vehicles are progressively substituted with electric.

The road transport transition also requires investment in public charging infrastructure and associated grids. In addition, average annual spending on private EV chargers in the selected emerging economies needs to increase to nearly USD 40 billion in 2026-2030 in the APS, compared to less than USD 1.0 billion annually in 2016-2021.

Limited financing presents a significant barrier for major road transport investments in emerging economies. Strained public sector budgets, lack of household capital, shallow banking systems, limited availability of loans, and high capital costs all hamper development of the sector. Strengthening domestic banks and household finances, removing market distortions, and targeted use of state-owned enterprises to create demand are key elements to address financial obstacles and to channel investments. International finance instruments such as overseas development aid, climate finance, multilateral finance, as well as blended finance (such as the Just Energy Transition Partnerships with South Africa and Indonesia), can also help overcome financing barriers.

Conclusion and recommendations

Governments have a large potential toolbox at hand to decarbonise the road transport sector, and a mix of targets, policies and regulations will be needed to align road transport in major emerging economies along an APS pathway. These policies will shape the technological development of different powertrains and transport modes and will influence consumer purchasing decisions.

Strengthen transport policy making:

A robust road transport transition requires an overarching transport decarbonisation strategy within a national transport plan. Developing a comprehensive national transport plan should involve all key stakeholders to garner acceptance. South Africa's Green Transport Strategy, for example, aims to build a safe, efficient, reliable, and affordable transport system that supports sustainable socio-economic development. In many major emerging economies, several institutions and agencies have roles in the transport sector. Transitions in the road transport sector could also be reinforced by introducing carbon pricing, complemented by targeted support for vulnerable and low-income households.

Promote public transport and demand management:

Policies that incentivise shifts from privately owned vehicles to public transport, in both urban and rural areas, are needed to reduce demand for car use while encouraging safer mobility and reducing congestion. The Curitiba bus rapid transit system in Brazil and the TransJakarta bus rapid transit system in Indonesia are successful examples. Electrification of buses and trains accelerates the decarbonisation of public transport while reducing air pollution. Public procurement requirements for zero-emission vehicles, subsidies for the purchase of electric buses, and CO_2 standards can support this shift. Public transport measures should be supported with initiatives to encourage and enable active mobility such as cycling, walking or other innovative measures to limit use of private car transport for short-distance trips. Colombia, for example, adopted a law in 2016 that strongly incentivises employees to cycle to work while Mexico City added around 50 km of bike lanes during the pandemic and plans to increase the length of its bike lanes to 600 km by 2024.

Accelerate the electrification of cars and two-/three-wheelers:

While EV and battery costs have declined, EVs remain much more expensive than comparable internal combustions engine (ICE) models. A growing number of major emerging economies are introducing or expanding purchase subsidies: India extended its flagship FAME programme in 2019, while China and Indonesia reduced purchase taxes for EVs. Measures such as special lanes, parking spaces, and zero-emissions zones have been introduced in China and parts of India to bolster demand for EVs without imposing significant cost on the state. Fleet mandates can stimulate demand for EVs: the Government of Delhi proposed a draft regulation in July 2022 requiring delivery and transportation businesses to electrify some of their fleet, with required shares increasing over time.

Prioritising an early transition of fleet vehicles can also help establish a second-hand market for EVs, which in turn would make electric cars more affordable for much of the population. Policy makers need to ensure that sufficient, reliable, and easy-to-use charging is available. Most charging takes place at home and at workplaces, and many countries offer subsidies or tax incentives to encourage private investment. India, for example, integrated a target of up to 20% of parking space for EV charging facilities in its Electric Vehicle Supply Equipment building code. In many emerging economies, battery swapping allows the sale of EVs without batteries, lowering upfront purchase costs.

Enhance fuel economy standards:

Fuel economy standards, if set at sufficiently stringent levels and regularly updated, can push manufacturers to produce zero- and low-emissions vehicles instead of focusing on improving the fuel efficiency of ICEs. Standards must be developed and applied within a robust regulatory framework, ideally based on testing procedures that reflects real-world driving conditions, such as the Worldwide Harmonised Light Vehicle Test Procedure.

Zero-emissions truck regulations and standards can also incentivise market demand for electric and fuel cell trucks, while binding targets such as California's Advanced Clean Truck Regulation can provide important signals to the market. Public and private sector research and development (R&D) investment and market regulations can be combined with domestic, regional, or global partnership programmes to create an ecosystem of regulators, manufacturers, and research organisations to accelerate innovation in the trucking sector. Measures to improve flow and logistics can optimise road freight transport usage and mitigate some of its CO_2 emissions. Brazil uses its PortoLog system to coordinate the arrival of ships and trucks at terminals, minimising waiting times for both.

Boost the uptake of sustainable biofuels:

Blending mandates remain the principal policy instrument to accelerate biofuel use. Indonesia supports its blending mandates with subsidies to offset price differences between biodiesel and conventional diesel. Government programmes and industry innovation will be needed to strengthen supply chains, seek out new sources of supply, and develop new production techniques.

Finance and investment

Emerging market and developing economies rely to a large extent on public finance to fund the transition. These sources include public institutions, such as development banks and infrastructure funds, which play important roles by extending credit lines and guarantees to financial institutions and companies, reducing risks and improving the bankability of projects. In the transport sector, most future investments in end-uses by 2030, notably EVs and EV-related energy efficiency, are expected to come from private sources. Public financing continues to help de-risk investment and attract private investment. It also supports market uptake through public procurement and provision of grants or guarantees to consumers and infrastructure, such as EV charging stations and mass transit.

Indonesia, for example, has identified public-private partnerships as a key mechanism to encourage private investment to meet some of its funding needs to address infrastructure gaps. The country has established a comprehensive policy framework and governance structure, supported by several public financing instruments, as well as a dedicated unit for public-private partnership management within the Ministry of Finance.

Taxonomies can strengthen sustainable finance frameworks. China, for example, issued a Green Bond Endorsed Projects Catalogue to guide financial institutions and corporate institutions on the issuance of green bonds.

Developing corporate bond markets to make debt finance more accessible to the private sector can play an important role in reducing the cost of capital for clean energy transition projects. Measures such as consumer car loans to purchase zero-emission vehicles also make a difference. South Africa established the Climate Finance Facility, which is a specialised lending facility to increase private investment in climate-related infrastructure projects.

Strategic mandates on clean energy transitions for international financial institutions (e.g., multilateral development banks) and greater use of blended finance to leverage private capital can be used to lower costs and support availability of longer-term capital. The South Africa and Indonesia Just Energy Transition Partnerships are examples of international co-operation in financing clean energy transitions in emerging economies which could be extended to the transport sector.

Chapter 1. Road transport today

Road transport accounted for around 20% of global final energy consumption and about 50% of global oil demand in 2021. This is a similar share to 2000, despite rising demand for transport services and vehicle numbers. The selected major emerging economies analysed in this report – Brazil, People's Republic of China ("China" hereafter), India, Indonesia, Mexico and South Africa[2] – represented around 14% of global road transport energy demand in 2000. In 2021, this share increased to 27%.

Demand for the transport of people and goods increased significantly from 2000 to 2021 owing to population growth and economic expansion. This trend was more pronounced in some of the selected emerging economies, notably China, India and Indonesia.

In 2021, Covid-19 pandemic restrictions were lifted and passenger and goods movements recovered following a decline in 2020. As a result, global direct CO_2 emissions owing to fossil fuel combustion in the transport sector increased by 8%, to nearly 7.7 Gt CO_2, compared to 7.1 Gt CO_2 in 2020. Transport demand is projected to climb in coming years as demand for goods and movement increases. Meeting the IEA Announced Pledges Scenario (APS) however, will require transport sector emissions to fall by almost 50%, to about 4 Gt CO_2 in annual emissions by 2030.

More than 95% of CO_2 emissions in the road transport sector in 2021 were attributable to oil consumption. Road transport is the largest consumer of fossil fuels of any sector. It accounts for around 30% of global CO_2 emissions from end-use sectors.

The selected emerging economies made up around a quarter of global CO_2 emissions from road transport in 2021 compared to 14% in 2000. In absolute terms, direct CO_2 emissions from road transport in these major emerging economies almost tripled from 2000 to 2021, whereas global CO_2 emissions from the sector increased by around 38%. While per capita CO_2 emissions from road transport are rising in these major emerging economies, they remain well below those of advanced economies, for example: 0.6 t CO_2 in China, 0.2 t CO_2 in India and 0.7 t CO_2 in South Africa compared to 2.1 t CO_2 per capita in advanced economies.[3]

[2] When this report refers to selected major emerging economies or selected emerging economies, it always pertains to the analysed countries of Brazil, China, India, Indonesia, Mexico and South Africa.
[3] Advanced economies refer to the Organisation for Economic Co-operation and Development regional grouping and Bulgaria, Croatia, Cyprus, Malta and Romania.

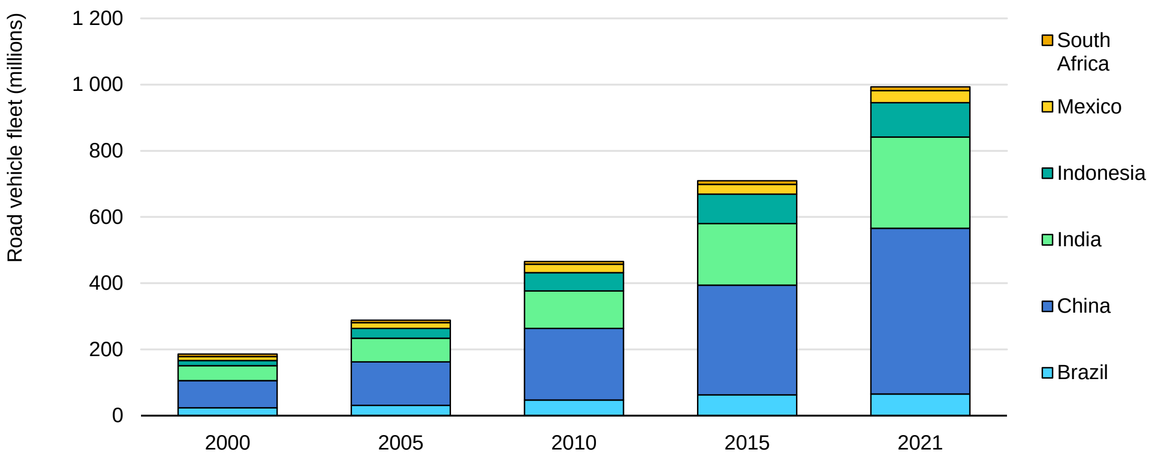
Projected growth in population, economic activity and transport demand demonstrates that energy transitions in the road transport sector will require a range of government decisions before 2030 to simultaneously meet transport demand and clean energy objectives.

This chapter sets out the status of the road transport sector in the selected emerging economies. It assesses trends in terms of the composition of the vehicle fleet, the structural factors underlying those changes, the implications of growth in vehicle numbers in terms of CO_2 emissions and how the sector has evolved in terms of investment since 2000. The chapter closes with a brief description of the IEA World Energy Outlook scenarios utilised in the report.

Composition of road transport

In 2021, there were around 2.3 billion vehicles (including two- and three-wheelers) on the world's roads. Cars[4] accounted for the bulk of the global vehicle stock, with around 1.4 billion vehicles compared to around 800 million two decades previously. In contrast, in the selected emerging economies, two- and three-wheelers outnumbered cars.

Figure 1.1 Road vehicle fleet, 2000-2021



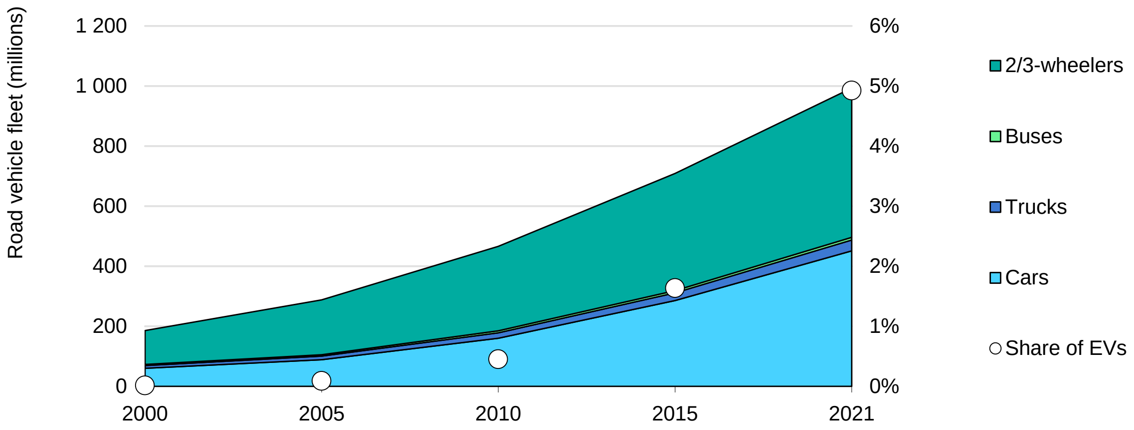
The number of vehicles in these major emerging economies has increased substantially over the last two decades. In 2000, their total vehicle stock was around 185 million. At the end of 2021, it was about 1 billion, or a near fivefold increase. This compares to an increase of 42% in the rest of the world over the

[4] Except where otherwise indicated, in this report, the category "cars" consists of personal light-duty vehicles and light commercial vehicles, while "trucks" consists of medium-freight trucks and heavy-freight trucks.

same period. China accounted for 52% of the increase, followed by India (29%) and Indonesia (11%).

In 2000, the vehicle stock per 1 000 inhabitants in advanced economies was around 460 vehicles; by 2021 it had increased to 480 vehicles per 1 000 inhabitants. In China, the vehicle stock per 1 000 inhabitants was around 65 vehicles in 2000; in 2021, it had increased to more than 350 vehicles per 1 000 inhabitants. This is above the global average of around 290 vehicles per 1 000 inhabitants, but below that of advanced economies.

Figure 1.2 Road vehicle fleet by mode and share of electric vehicles in selected major emerging economies, 2000-2021

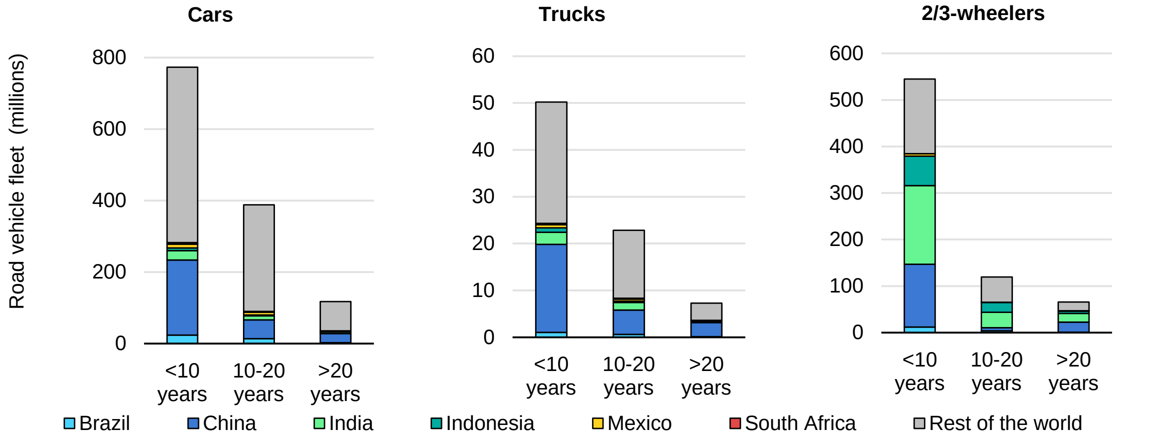


The rate of increase in vehicle numbers varied across modes of road transport and among the selected emerging economies since 2000. Cars (almost sevenfold increase) and two- and three-wheelers (more than threefold increase) had the greatest rates of increase in numbers, supported by strong economic growth and the resultant increase in demand for mobility. The number of trucks has also rose significantly, by almost 300%, as incomes rose and demand for goods increased among these major emerging economies.

In 2000, the two- and three-wheelers (61%) and cars (32%) subsectors accounted for most of the vehicles on roads. While they continue to represent the bulk of vehicles, in 2021, their shares changed. The share of two- and three-wheelers declined to 50% of all vehicles, and the share of cars to 45%, reflecting increased income and related changes in consumer preferences.

The share of EVs in the vehicle fleet increased greatly over the past two decades. In 2010, the share was less than 1%. The share increased to 5% in 2021 and to almost 50 million vehicles in the selected emerging economies. However, this increase is highly concentrated: China accounted for the highest share of EVs (48 million vehicles in 2021), over 80% of which were two- and three-wheelers.

Figure 1.3 Age profile and geographic distribution of road transport vehicles, 2021

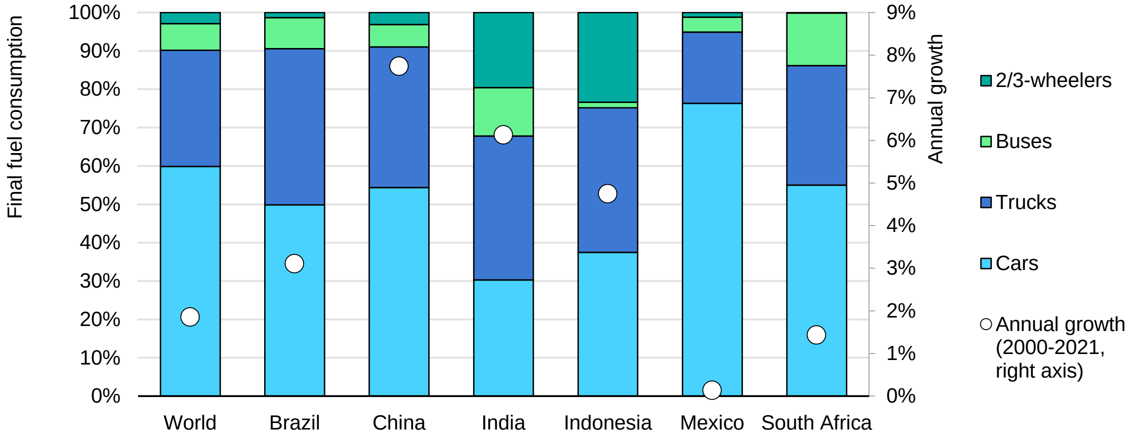


Source: Adapted and updated from IEA (2020), Energy Technology Perspectives 2020.

By the end of 2021, the global passenger car fleet was about 1.2 billion vehicles, with advanced economies accounting for almost 70% of the total. Broadly speaking, the fleets in the selected emerging economies are younger than in many other countries, in particular advanced economies.

Since 2010, there has been a dramatic shift in the location of where new cars are sold. China overtook the European and North American markets in the early 2010s. The result is that the car fleet in the selected emerging economies is newer than in advanced ones. Around 70% of the cars on China's roads are less than a decade old. Trucks and buses follow the same general pattern. However, the shifts in new sales of these modes are even starker. Most trucks sold in the past decade were in these major emerging economies, as were two-thirds of buses.

Figure 1.4 Road transport fuel consumption by mode, 2021



Fuel consumption patterns vary significantly among the selected emerging economies. This reflects the various structural differences and geographies and the resultant demand for transport services. Those countries that experience the highest levels of economic growth also have the greatest increases in demand for transport services. In Brazil, China, Mexico and South Africa, the cars subsector accounted for the largest share of fuel consumption; in India and Indonesia, the trucks subsector consumes most fuel.

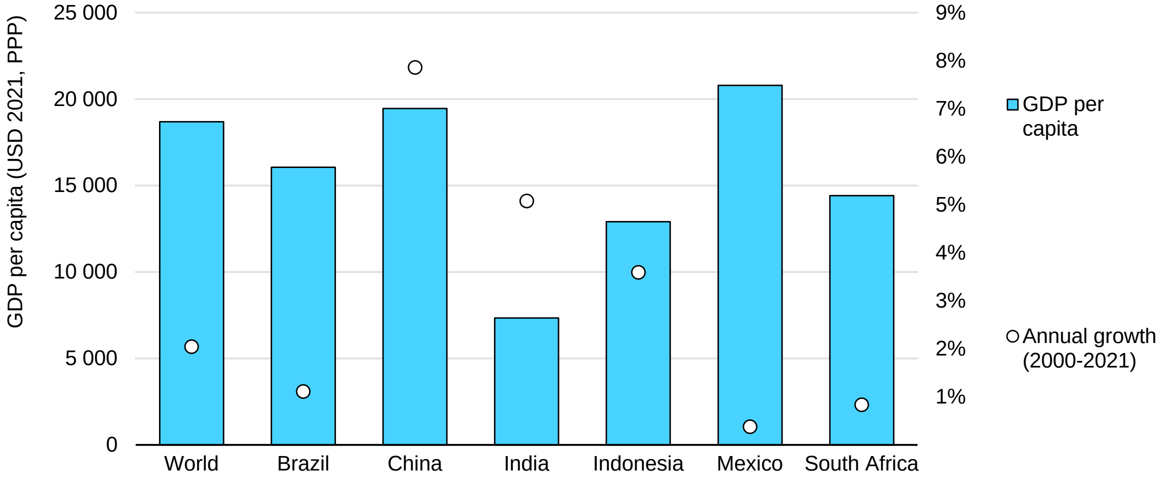
Structural drivers of change

The evolution of transport energy demand and greenhouse gas (GHG) emissions depends on factors such as changes in transport activity, shares of activity in different transport modes, the energy efficiency of each mode and the carbon content of fuels. Differing characteristics of urban and non-urban mobility also shape the trajectory of shape the trajectory of energy and emissions from transport from transport.

In many selected emerging economies, where average income and car ownership levels are lower than in advanced economies while a larger share of travel occurs by public transport (bus and rail). Transport activity varies greatly; for example, in Indonesia and South Africa, bus travel is the primary mode of transport, whereas rail travel is more widespread in China and India. In contrast, Mexico has a high share of passenger activity in cars and high ownership of large cars. This may be influenced by the country being an oil producer and an importer of used cars from the United States.

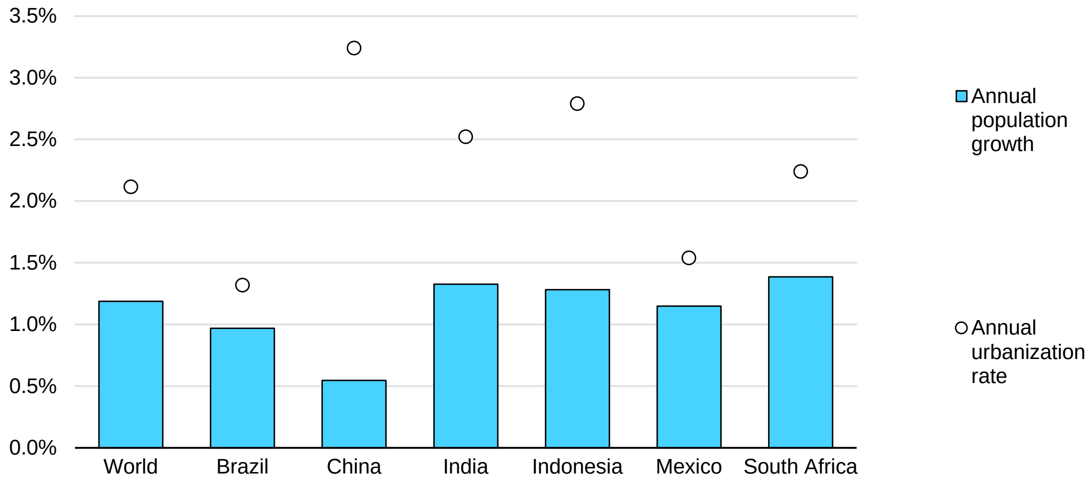
World gross domestic product (GDP) per capita increased at an annual average rate of 2% a year from 2000 to 2021. Growth among the selected emerging economies varied significantly over the same period. Populations and urbanisation rates have also increased, which, together with economic growth, affect transport and energy use.

Figure 1.5 GDP per capita and growth rate, 2021



Growing economies generate demand for goods and services; therefore, demand for transport tends to increase as economies grow. Data for the past 20 years suggest this has been the case for the selected emerging economies. China, India and Indonesia have all experienced rapid economic growth over the past two decades. In the case of China, the economy expanded at an annual average rate of almost 8% a year on a per capita basis from 2000 to 2021. In India, it has been 5% and in Indonesia around 3.5%. Economic growth has been less pronounced over the same period in Brazil, Mexico and South Africa, where the economies expanded by around 0.5-1% on a per capita basis.

Figure 1.6 Annual population growth and urbanisation rate, 2000-2021



India, China and Indonesia have experienced the largest population increases, most notably India, where the population increased by around 335 million over the past two decades. China's population grew at a slower pace and increased by around 150 million people, while Indonesia's population expanded by 65 million. Together, these three countries accounted for a third of the increase in the world's population over the past 20 years.

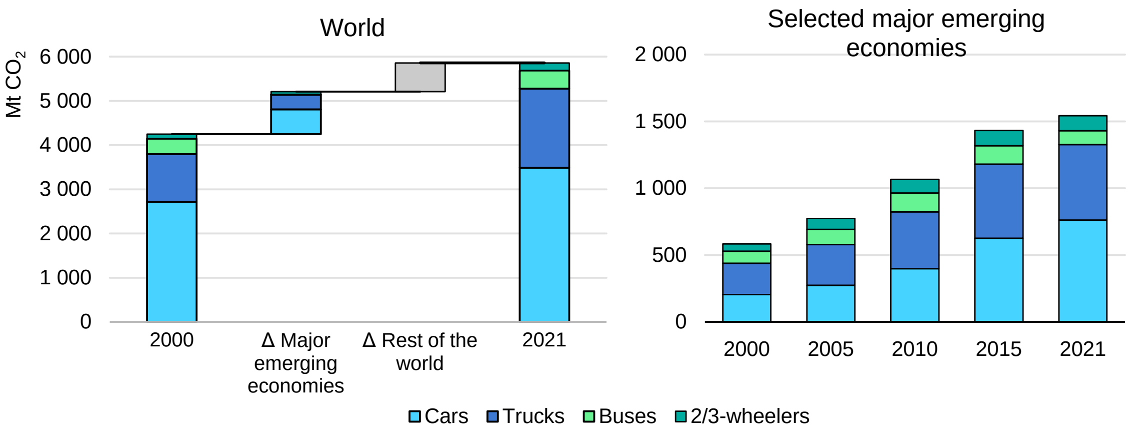
Globally, about half of total passenger transport activity (measured in passenger kilometres) now takes place in urban environments. Rising incomes have driven demand for more mobility, as well as the greater comfort and status afforded by personal vehicles. This demand is expected to continue as incomes rise across a wider range of countries and a broader base of populations.

All the selected emerging economies have experienced growth in urbanisation rates, reflecting a global trend over the past 20 years as more people move to cities for better opportunities, jobs and income. Continued rapid urbanisation and industrialisation pushes up demand for services such as transport. In 2000, less than half of the world's population lived in urban areas; in 2021, this rate had increased to 57%. In China, the rate of urbanisation increased from 36% to 62% over the same period, and in Indonesia, it grew from 42% to 57%. Brazil and Mexico are among the most urbanised countries in the world, which explains their lower annual urbanisation rates.

Development of CO_2 emissions

Global CO_2 emissions in the road transport sector increased by 38% from 2000 to 2021, from around 4 250 Mt CO_2 to 5 860 Mt CO_2. The selected emerging economies accounted for around 60% of this increase, with increased emissions from cars, vans and trucks. China and India accounted for the largest shares of the increases.

Figure 1.7 Evolution of road transport CO_2 emissions by mode, 2000-2021

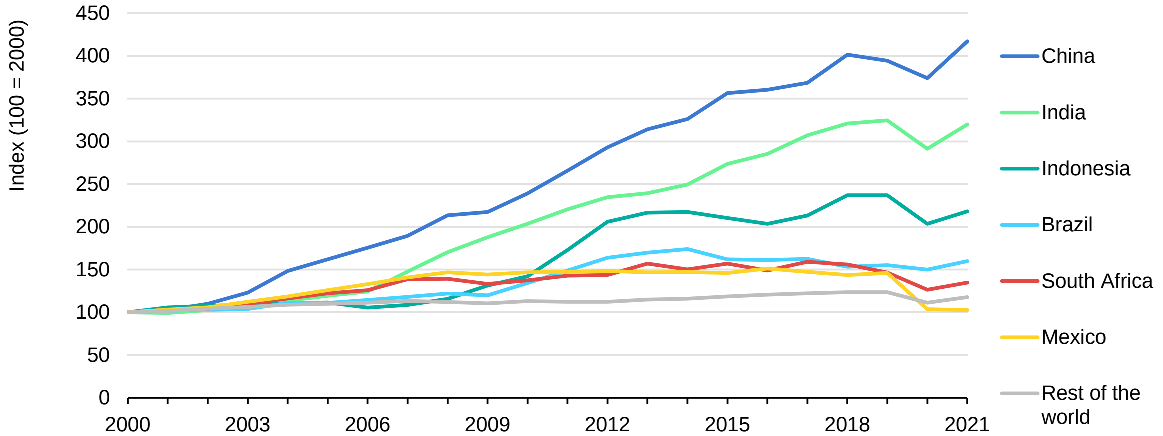


The cars subsector accounted for about 13% of global direct CO_2 emissions in 2021. The specific fuel consumption of new vehicles has declined, owing to improvements in engine, powertrain and vehicle technology. However, a long-term trend of increasing vehicle size and power has slowed progress. To remain on track with the pathway in the APS, much more rapid improvements in the fuel economy of new conventional (ICE) vehicles are needed, even as the share of EV sales continues to grow.

CO_2 emissions from road transport in the selected emerging economies increased significantly from 2000 to 2021. In 2000, direct CO_2 emissions from the sector were 583 Mt CO_2; in 2021, this had more than doubled, to around 1 540 Mt CO_2. However, the rate of increase in emissions was lower than that of the number of vehicles on the road.

Trucks (40%) and cars (35%) accounted for three-quarters of road transport CO_2 emissions in 2000 in selected emerging economies. In 2021, their combined share had increased to 86%. In contrast, the share of sector emissions from two- and three-wheelers declined from 9% in 2000 to 7% in 2021, despite more than quadrupling in number. This decline reflects increasing electrification rates in China. Heavy-freight trucks, which accounted for less than 2% of all vehicles on the road in 2021 in the selected emerging economies, contributed 25% of all CO_2 emissions in the sector.

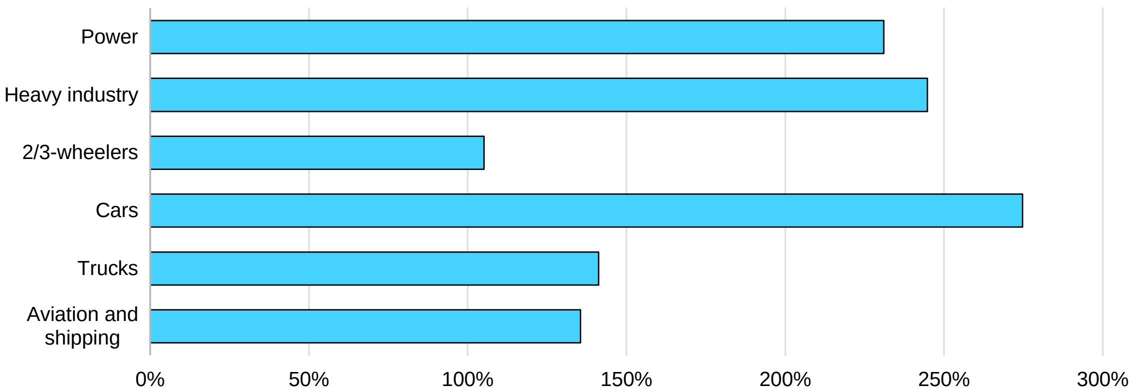
Figure 1.8 Road transport CO_2 emissions, 2000-2021



Historical trends of CO_2 emissions vary notably among selected emerging economies. China has experienced the largest increase in relative terms, with emissions from road transport more than quadrupling from 2000 to 2021. Over the same period, China's GDP per capita increased fivefold, triggering increased demand for transport services, with 290 million cars on the road in 2021 compared to 8.2 million in 2000.

India and Indonesia also experienced robust growth over the same period, with emissions from road transport tripling in India and more than doubling in Indonesia. In India, the total stock of road vehicles grew from around an estimated 45 million in 2000 to more than 275 million in 2021. In Indonesia, the number of vehicles on roads increased from 16 million in 2000 to around 105 million in 2021, notably driven by the two- and three-wheelers subsector.

Figure 1.9 Growth of CO_2 emissions in certain energy sectors for the selected major emerging economies, 2000-2021



Total direct CO_2 emissions of the selected emerging economies increased by 180% from 2000 to 2021. Power generation, heavy industry and road transport were the main drivers of this increase. The cars subsector accounted for around 6% of the increase as emissions rose by almost 275% over the same period. The trucks and two- and three-wheelers subsectors accounted for another 4% of the increase.

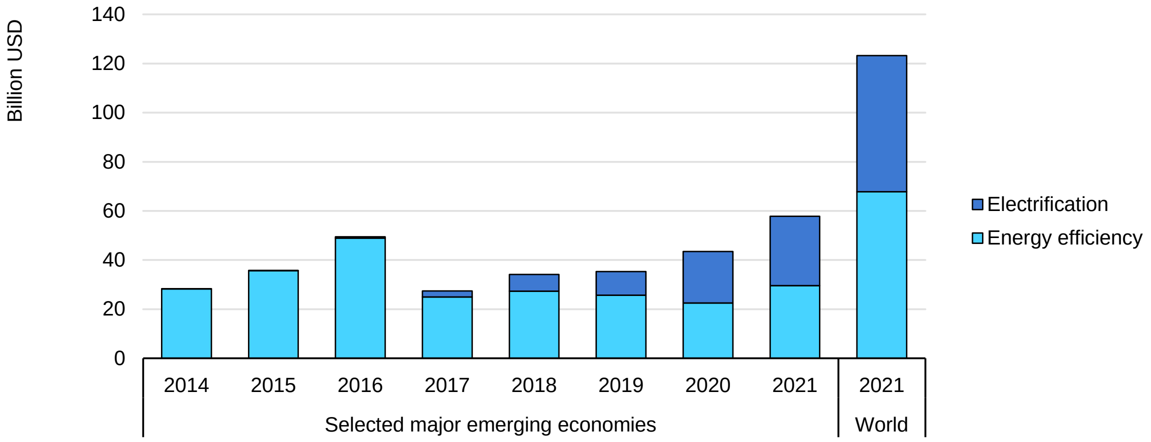
A notable feature of the market for cars is the growth in sports utility vehicle (SUV) sales. SUVs are heavier and consume around 20% more oil than average medium-sized cars. Increased sales of SUV is slowing progress in fuel economy improvements for vehicles powered by fossil fuels, which still account for most vehicles sold (electric car sales accounted for 9% of the global car market in 2021). Accordingly, SUVs rank among the top causes of the growth in energy-related CO_2 emissions since 2010. In 2021 alone, the global fleet of SUVs increased by over 35 million, driving up annual emissions by nearly 1 Gt CO_2. In India, SUV sales are lower than in China, at around 40%, but consumer preferences are changing with increasing income levels and with more people being able more people to can afford SUVs. At the same time, original equipment manufacturers are marketing towards this segment.

Road transport investment

End-use investment in road transport[5] in the selected emerging economies was around USD 60 billion in 2021. Energy efficiency accounted for a little over half, and electrification for the remainder. Since 2017, investment in electrification has increased significantly, from almost USD 5 billion to around USD 55 billion in 2021. Growth in EV sales is driving investment in electrification, which represented more than 45% of overall end-use investment in the global transport sector in 2021. Global EV sales more than doubled in 2021 compared to in 2020, with most of the growth in China and Europe, where, for the first time, EV surpassed diesel vehicle sales. In China, the median price of an EV in 2021 was only 10% above that of the overall fleet. In contrast, model availability in the other selected emerging economies (outside China) in 2021 was limited and prices high.

[5] This includes investment in energy efficiency and electrification. Energy efficiency pertains to investments in vehicle efficiency, and electrification to investment in EVs.

Figure 1.10 Investment in road transport, 2014-2021



Sustainable biofuels play an important role in decarbonising road transport. They provide a low-carbon solution for existing technologies, such as for cars in the near term and for trucks and buses in the long term. Global investment in liquid biofuels (bio-gasoline and biodiesel) more than doubled in 2021, reaching just over USD 8 billion. Two-thirds of this growth was in bio-based diesel, spurred by rising investment in hydrotreated vegetable oil renewable diesel, although ethanol investment also nearly doubled. Brazil contributed around 30% to global investment in liquid biofuels in 2021.

Box 1.1 Fossil fuel subsidies and energy transitions

Some emerging market and developing economies continue to support the production and consumption of coal, oil and natural gas. This is despite a 2009 pledge by G20 countries to gradually phase out inefficient fossil fuel subsidies.

Price interventions such as fossil fuel subsidies are rarely well designed or targeted to the most vulnerable. These subsidies diminish or remove the incentives to shift to more efficient and electrified transport and tend to disproportionately benefit wealthier households and businesses. They also burden government finances at a time when fiscal leeway is important to accelerate clean energy transitions.

Sustainable energy investments face an uphill struggle in many emerging markets and developing economies (EMDEs). This is because regulated prices or taxes favour fossil fuels.

In 2020, the fall in fossil fuel demand and prices due to the Covid-19 pandemic drove the value of fossil fuel consumption subsidies* down to a record low. The IEA estimated that the economic value of global fossil fuel subsidies was more than USD 215 billion in 2020, 50% below 2019 levels and the lowest annual figure since the IEA began tracking these subsidies in 2007. Many countries therefore took advantage of the low prices and world demand to reform pricing. For example, Indonesia cut the subsidy for diesel by 50% to IDR 500/litre, while in India, the government raised excise duties on gasoline and diesel in response to the drop in international prices.

In 2022, the global economic recovery and energy crisis increased oil prices, and the IEA estimates fossil fuel subsidies reached an all-time high of all-time high of USD 1 trillion. Some countries introduced temporary measures to cushion the effect of rising oil prices on consumers (e.g., South Africa reduced excise taxes on gasoline and diesel until February 2023). Among the selected emerging economies, only Indonesia retains subsidies for transport oil consumption, spending more than USD 13 billion in 2021 compared to USD 2.5 billion in 2020 and USD 15 billion in 2019. India ended direct subsidies for transport oil consumption in 2015, while Mexico did so in 2014.

* IEA methodology uses a price-gap analysis to estimate subsidies. This is an approach that tries to identify the gap by comparing reference prices with end-user prices for consumers.

Source: IEA (2023), Energy Subsidies: Tracking the impact of fossil-fuel subsidies.

IEA World Energy Outlook scenarios

Much of the quantitative analysis contained in this report is based on scenarios developed for the IEA World Energy Outlook (WEO). The WEO explores various scenarios, each of which is built on a different set of underlying assumptions about how the energy system might evolve.

These scenarios are not predictions, and the IEA does not have a single view about what the long-term future might hold. Instead, the WEO scenarios seek to compare different possible versions of the future and explore which levers and actions shape them, with the aim of stimulating insights about the future of global energy.

The scenarios highlight the importance of government policies in determining the future of the global energy system. Decisions made by governments are the main differentiating factor explaining the variations in outcomes across the IEA scenarios. The IEA also considers other elements and influences, notably the economic and demographic context, technology costs and learning, energy prices and affordability, corporate sustainability commitments, and social and behavioural factors.

This report utilises two of the main World Energy Outlook 2022 scenarios. The two scenarios are exploratory, in that they define a set of starting conditions and then explore where they lead.

The first of these is the Stated Policies Scenario (STEPS), which the IEA uses as a reference against which to explore the implications of the APS. The STEPS takes a more conservative approach over the implementation of policies than the APS, integrating sector-by-sector analysis of the impacts of established and announced policies and regulations. Outside of these policies, the evolution of the energy system in the STEPS is driven by infrastructure and equipment lifetimes, energy technology costs, fuel prices and consumer preferences.

The second scenario utilised in this report is the APS, which was first introduced into the IEA scenario framework in 2021, to reflect the growing number of countries with announced net zero emissions targets. The APS assumes governments achieve their targets on time and in full, regardless of whether they are backed by detailed implementing laws, policies and regulations. It also considers how countries envisage different sectors, such as energy and agriculture, forestry and other land use, contributing to the goal of net zero emissions.[6]

[6] The mitigation potential of agriculture, forestry and other land use is derived from removals of GHGs and emissions reductions through management of land and livestock.

Chapter 2. Road transport at a crossroads

It is important to understand where the road transport sector could be heading in the future, given the tripling of road transport CO_2 emissions in the selected emerging economies over the past two decades. In light of net zero pledges,[7] it is also important to understand where it could be heading with enhanced policy ambition.

Road transport is at a crossroads. Despite a rise in the number EVs, road transport could remain a sector largely dependent on oil consumption, emitting significant quantities of CO_2 emissions and contributing to climate change. Alternatively, the sector could become a hub of transformation that delivers the increased needs for mobility and freight transport, with a fleet that is more efficient, and which runs mainly on electricity – consequently with significantly lower CO_2 emissions.

This chapter discusses the development of road transport in the selected emerging economies until 2050 in both the Stated Policies Scenario (STEPS) and the Announced Pledges Scenario (APS) pathways, while presenting the policy packages in place to drive changes in this sector. It identifies the most cost-effective abatement solutions to shift from a STEPS to an APS pathway and finishes by examining the air quality and health co-benefits of doing so. It focuses on India and Indonesia, given their expected future growth trajectories in road transport.

Changes in fleets and fuels

In addition to the growth in the number of vehicles on the road in the selected emerging economies in the past two decades (see Chapter 1), these countries are likely to experience a near doubling of these numbers by 2050. The stock of vehicles could increase to 1.7 billion in the STEPS and to 1.8 billion in the APS, driven by economic and population growth. Personal vehicles such as cars, as well as two- and three-wheelers for personal and commercial use, particularly drive the increase in absolute numbers.

There could be about 50 million fewer cars on the roads of these countries in the APS compared to in the STEPS by 2050. However, this decline in numbers is

[7] Of the selected major emerging economies, the following net zero pledges have been made: Brazil, by 2060; China, before 2060; India, by 2070; Indonesia, by 2060; and South Africa, by 2050.

more than compensated for by almost 200 million more two- and three-wheelers. Modal shifts could reduce the use of personal cars in favour of other modes of transport such as public transport and more flexible two- and three-wheelers, especially in urban settings.

In contrast to the development of the past two decades, India – followed by China at some distance – is projected to become the major driver of continued growth in the stock of vehicles, contributing around half of the total growth in the selected emerging economies.

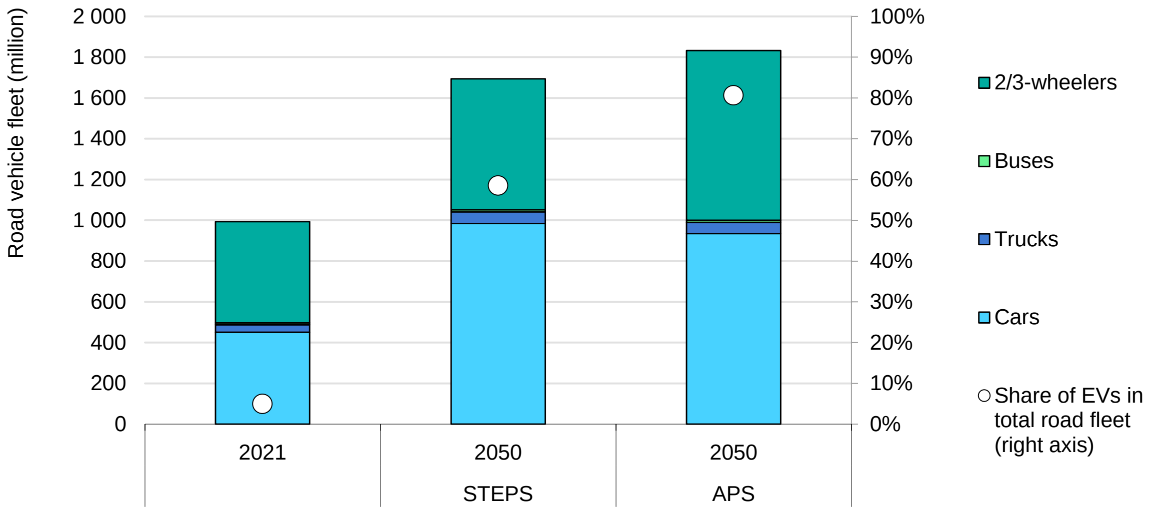
India's stock could increase from 280 million vehicles in 2021 to around 650 million by 2050. Its fleet of personal cars is projected to grow sixfold from 40 million in 2021 to 250 million, while the number of two- and three-wheelers almost doubles. These numbers outpace any of the other selected emerging economies in both vehicle categories. India's comparatively higher projected rate of economic and population growth is the underlying driver. It will make the purchase of a personal vehicle more affordable to more households.

The growth of electrification is another pronounced trend in the fleet composition of selected emerging economies. In 2021, the share of EVs in the total road vehicle stock was around 5% in those countries, but this will surge in both the STEPS and the APS by 2050.

In the STEPS, China will experience a significant growth of EVs, notably cars and two- and three-wheelers, reaching around 550 million EVs by 2050. India follows, reaching 330 million EVs – notably two- and three-wheelers. All selected emerging economies see a significant acceleration in the deployment of EVs due to an increased focus on road transport electrification and corresponding policy support.

Compared to the STEPS, in a scenario where countries meet their announced pledges (the APS), Mexico and South Africa increase their stock of EVs by factors of 4 and 5, respectively, by 2050. Brazil and Indonesia more than double theirs, while India's almost doubles. China experiences only a moderate boost in the APS compared to the STEPS. Market dynamics help to exceed China's stated targets, with the existing policy framework and targets to 2030 already taken into account in the STEPS, designed to meet the country's long-term carbon neutrality targets.

Figure 2.1 Road vehicle fleet and share of EVs in total road vehicle fleet in the selected major emerging economies, in the Stated Policies Scenario and the Announced Pledges Scenario, 2021-2050



Fuel consumption in the road transport sector of selected emerging economies is especially from fossil fuels. In 2021, gasoline and diesel, and to a small extent natural gas, served more than 90% of total fuel demand (560 Mtoe) in the sector, with electricity accounting for less than 1%. Biofuel strategies have helped to drive up the consumption of biofuels – from 6 Mtoe in 2000 to 30 Mtoe in 2021 – with Brazil and Indonesia representing almost 85% of consumption in the selected emerging economies.

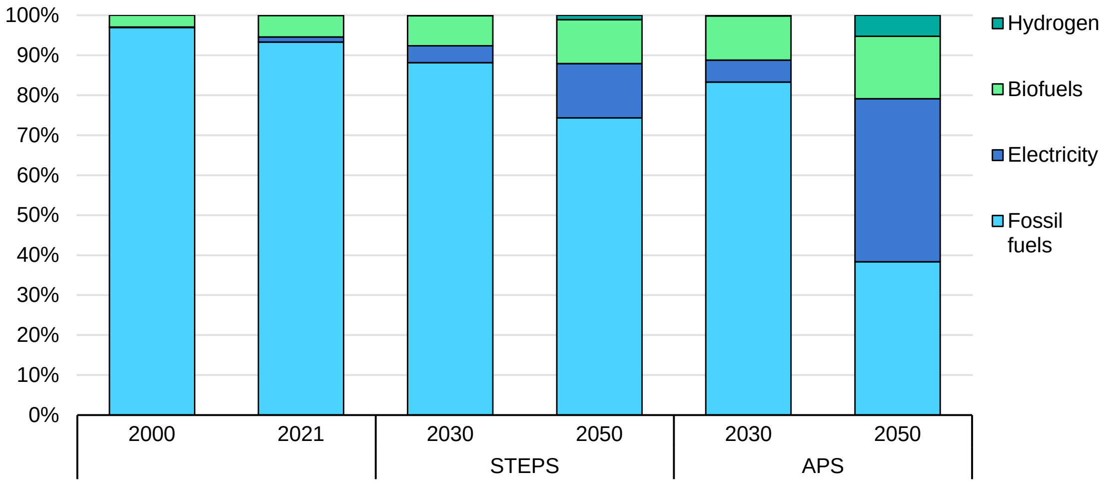
In the STEPS, total road transport fuel consumption of selected emerging economies is projected to rise to 725 Mtoe by 2050. Consumption of fossil fuels is expected to peak around 2030, slowly declining thereafter to around 540 Mtoe by mid-century. Biofuels continue their increase, albeit at a slower rate. Electricity is poised to become the second most dominant fuel after fossil fuels, supported by an increase in EV use, notably in China and India. Electricity and biofuel use rises in Brazil, India and Indonesia, but would account for around only 25% of the 2050 fuel consumption. The increase in electric two- and three-wheelers and cars with electric powertrains explains the high share of EVs in the total road fleet in the STEPS. However, most cars and trucks in the selected emerging economies would still be powered by fossil fuels.

In the APS, the selected emerging economies could see total fuel consumption in the road transport sector peak at around 660 Mtoe by 2030. Fuel economy improvements could drive fuel consumption down to 500 Mtoe by 2050 (lower than 2021 levels), despite continued growth in the number of vehicles. In the APS, road transport fuel consumption in those countries could experience a dramatic shift to electricity and, to a lesser extent, to hydrogen, compared to the STEPS.

By 2050, in the APS, electricity could become the most used form of energy in the selected emerging economies. It could represent more than 40% of consumption, driven by an aggressive expansion of EVs across the cars, trucks, and two- and three-wheelers subsectors. This expansion of the EV fleet illustrates the importance of the parallel decarbonisation of the electricity system and modernisation of the electricity grid. However, large differences would exist among countries. Electricity consumption could be more than double that of fossil fuels in China's road transport sector. But in other countries such as India or Indonesia, fossil fuels rather than electricity would remain the dominant source to power vehicles on their roads.

In the APS, in terms of overall road transport consumption by 2050 in the selected emerging economies, electricity is closely followed by fossil fuels (mainly oil) at around 190 Mtoe. This is a level last seen in 2000. Biofuels could achieve similar levels in the APS to the STEPS. Hydrogen is expected to play a limited role in the road transport sector overall, although the number of fuel cell electric cars, trucks and buses could start to grow in the 2040s. Total hydrogen consumption for road transport reaches more than 25 Mtoe in the APS by 2050.

Figure 2.2 Road transport fuel consumption in the selected major emerging economies in the Stated Policies Scenario and the Announced Pledges Scenario, 2000-2050



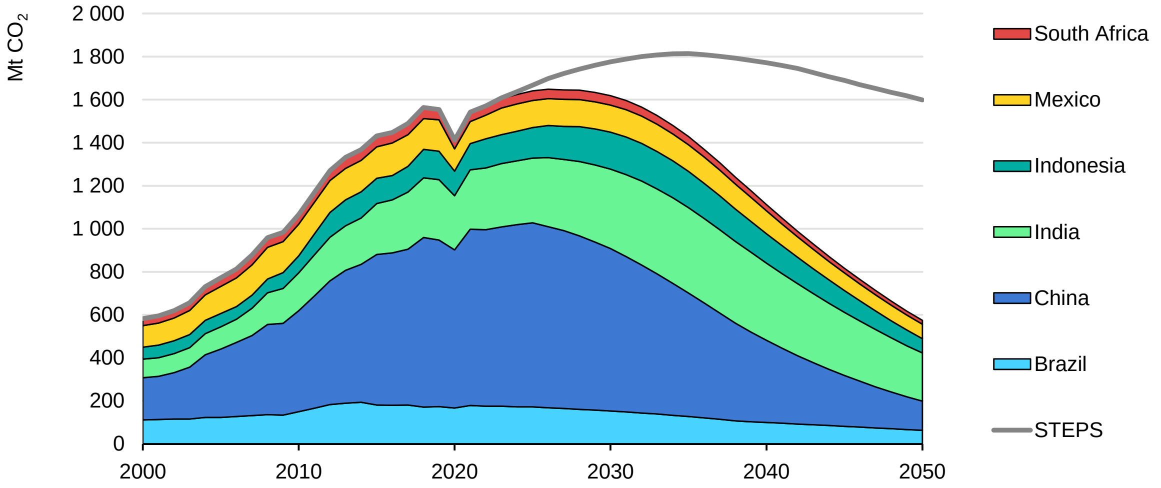
CO_2 emissions pathways

Direct CO_2 emissions from road transport reached more than 1.5 Gt CO_2 in the selected emerging economies in 2021. This increase was in line with the global rebound after Covid-19.

In the STEPS, such emissions continue to rise until mid-2030, thereafter decreasing slowly to 1.6 Gt CO_2 by 2050. This is the first time that the IEA's STEPS projects a plateauing and reduction of CO_2 emissions from the road transport sector in the selected emerging economies by mid-century. This development is attributable to declining emissions in China after 2025, with its emissions dropping by more than 40% compared to in 2021. In Brazil and India, emissions start decreasing after 2040. Indonesia's emissions stabilise towards 2050, while those of Mexico and South Africa continue to increase slowly.

In the APS, emissions from road transport in the selected emerging economies peak in 2025 and drop to less than 0.6 Gt CO_2 by 2050. China and India account for two-thirds of this decrease, due to the size of their fleets. China aims to achieve carbon neutrality before or by 2060 and India by 2070. In cumulative terms, ambitious policies in the APS in these major emerging economies could generate around 13 Gt CO_2 in cumulative emissions savings in the road transport sector by 2050, with the cars and trucks subsectors accounting for 95% of this reduction potential.

Figure 2.3 Road transport CO_2 emissions in the Announced Pledges Scenario versus the Stated Policies Scenario, 2000-2050



Note: The scope of emissions is direct CO_2 emissions. To achieve the CO_2 emissions reductions illustrated, the APS assumes a rapid decarbonisation of the power sector. Please see the box below on power sector decarbonisation for more information.

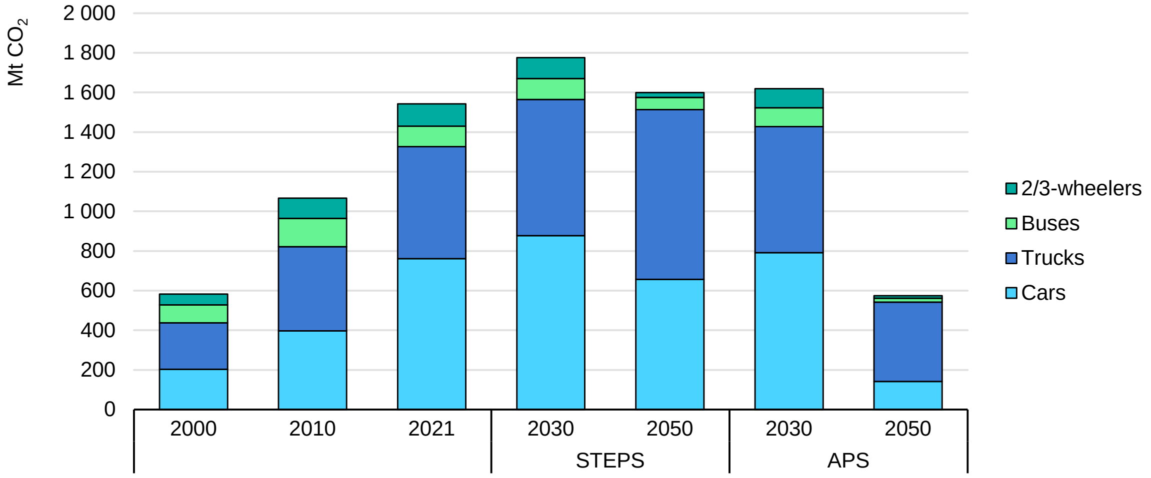
By 2030, the cars and trucks subsectors are projected to drive the increase in emissions in selected emerging economies in both scenarios. As populations and household incomes grow, the purchase of a private car becomes a viable option for more people, with the number of cars rising accordingly. By 2030, emissions due to cars will increase by 15% above 2021 levels in the STEPS (an increase of around 120 Mt CO_2), with about half the increase in CO_2 emissions related to road transport. In the APS, almost 90 Mt CO_2 of this rise could be shaved off as policies accelerate the adoption of EVs. For example, the share of electric cars in total car sales is projected to jump from around 1% in 2021 to 31% in India and 21% in Indonesia by 2030, compared to 13% and 7%, respectively, in the STEPS.

By 2050, emissions due to cars in the selected emerging economies could fall below 2021 levels in the STEPS while continuing to emit significant quantities of CO_2 into the atmosphere. This outlook changes significantly in the APS as cars realise their potential as the main abatement lever. The share of EVs could reach at least 70% of the total car stock in all the selected emerging economies except Brazil, which is projected to rely on a combination of electric and biofuel-powered vehicles to achieve its decarbonisation and development goals. This means direct emissions from the car fleet in these major emerging economies could drop to 140 Mt CO_2 by 2050, around 80% lower than in 2021.

With emissions due to trucks having already doubled in the past two decades in the selected emerging economies, it faces a more difficult decarbonisation pathway. This is because economic and population growth drive a surge in the demand for freight transport while emissions reduction measures such as direct electrification or fuel cell electric vehicles (FCEVs) are not always readily available or cost-effective.

In both scenarios, CO_2 emissions due to trucks are projected to continue with an upward trend until 2030. Beyond 2030, they remain hard to abate. the STEPS projects an almost linear upward trend from 2030 to 2050. However, in the APS, the truck emissions curve is bent in this time frame, lowering emissions from 565 Mt CO_2 in 2021 to 400 Mt CO_2 by 2050 in the selected emerging economies. This is despite a surge in freight activity and the resulting increase in the number of trucks on the road. This reduction is achieved by means of aggressive fuel economy improvements, as well as by switching powertrains from diesel to electric and fuel cell electric. The trucks subsector has by far the highest road transport emissions out of all the subsectors, even in the more ambitious APS pathway.

Figure 2.4 Road transport CO_2 emissions in the selected major emerging economies by mode in the Stated Policies Scenario and the Announced Pledges Scenario, 2000-2050



Box 2.1 Power sector decarbonisation in the selected emerging economies

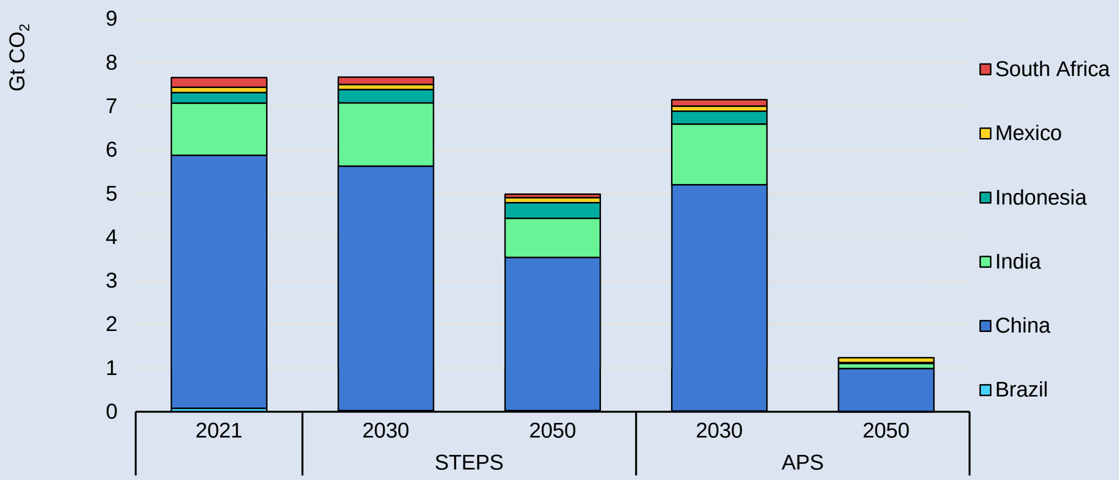
Power sector decarbonisation in the selected major emerging economies is a critical element in realising the full CO_2 emissions reduction potential of EVs. This is because vehicle charging can cause indirect emissions in electricity grids, with a high carbon intensity.

Globally, the electricity sector emitted 13 Gt CO_2 in 2021, with the selected emerging economies accounting for 60%, given the basic need to provide electricity to 3.5 billion people and the presence of large coal-fired power plant fleets in China, India, Indonesia and South Africa. However, in all scenarios, electricity sector CO_2 emissions peak soon, with steep reductions of 35% in the STEPS and over 80% in the APS by 2050 for these major emerging economies.

In the APS, China, which is the main contributor to this overall drop, sees its annual CO_2 emissions decline to 1 Gt CO_2 by 2050. In the other countries, they become almost insignificant or close to zero. A surge of renewable sources of energy in electricity generation and a significant reduction of the role of unabated coal-fired power mostly drive this development.

Higher investment in the electricity sector enables these reductions, rising from an annual average of USD 350 billion in 2017-2021 in the selected emerging economies to an annual average of USD 600 billion in 2022-2050 in the APS, or 30% higher than in the STEPS.

Power sector CO_2 emissions in the Stated Policies Scenario and the Announced Pledges Scenario, 2021-2050



Source: IEA (2022), World Energy Outlook 2022.

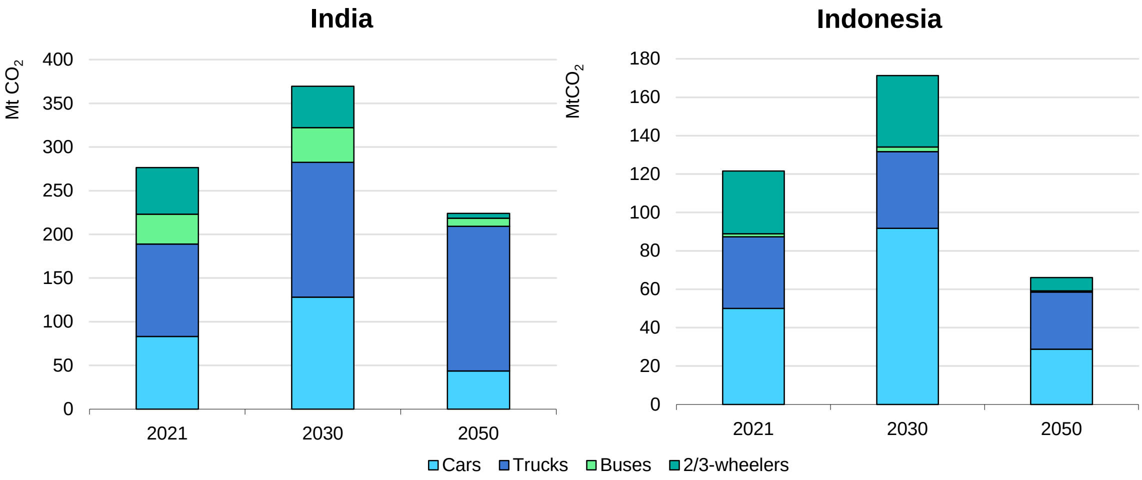
While power sector decarbonisation is essential to fully realise the emissions reduction potential of EVs, the net impact of EV use on emissions can be positive with current carbon intensities of electricity generation. When EV deployment displaces the use of conventional vehicles powered by fossil fuels, electricity carbon intensity needs to be lower than 700-750 g CO_2/kWh (around the current level of India's electricity generation) for the net impact of EV deployment to be positive.

Sources: IEA (2022), World Energy Outlook 2022; IEA (2021), Air Quality and Climate Policy Integration in India.

Road transport emissions in India and Indonesia

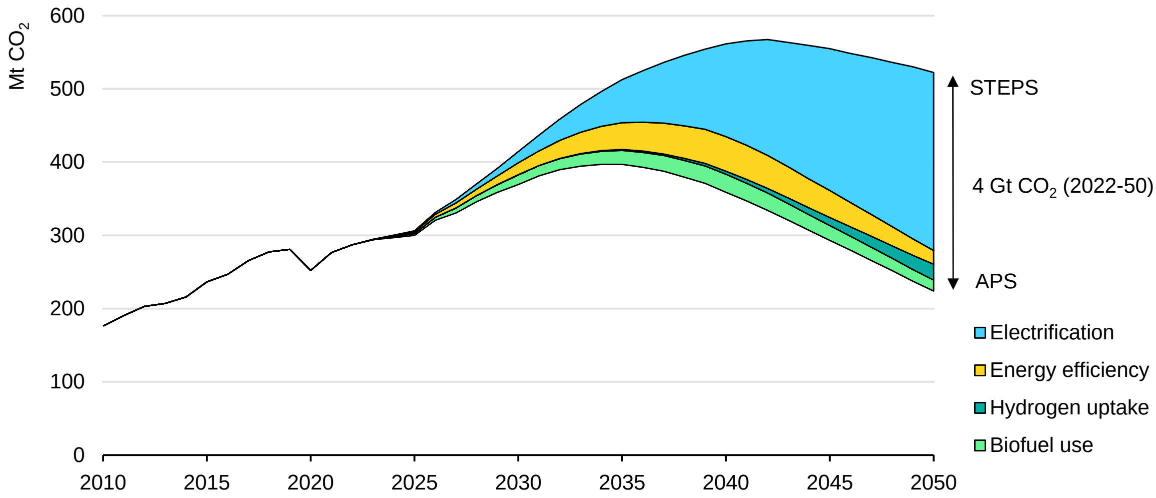
Together with China, India and Indonesia decrease their CO_2 emissions in the road transport sector significantly by 2050, in line with their net zero pledges, as modelled in the APS. However, both countries will have to significantly build out their current policy frameworks to achieve their net zero pledges and the resulting emissions pathways. When implementing the policies to achieve their pledges, both countries are expected to reach a peak in their road transport emissions in the mid-2030s.

Figure 2.5 Road transport CO_2 emissions in India and Indonesia by mode in the Announced Pledges Scenario, 2021-2050



In India, cars could be the main emissions reduction driver in the APS, followed by two- and three-wheelers and buses, owing to fleet electrification. Costs for electric cars and especially electric two- and three-wheelers are now, or soon will be, cost-competitive (see the section on cost-effective abatement solutions for further details). Truck emissions in India remain hard to abate until mid-century, as projected economic growth drives demand for freight transport and electric, while fuel cell electric trucks are likely to become cost-effective only in the 2040s.

Figure 2.6 Enablers of road transport decarbonisation in India, Announced Pledges Scenario versus Stated Policies Scenario, 2010-2050



Note: Includes direct and indirect CO_2 emissions.
Source: IEA (2023), Transitioning India's Road Transport Sector: Realising Climate and Air Quality Benefits.

Electrification enables the 4 Gt CO_2 in cumulative emissions savings from 2022 to 2050 in India's road transport decarbonisation in the APS. Energy efficiency – or fuel economy – improvements follow, with the annual savings contribution decreasing with time as efficiency improvements increasingly meet technical and physical limits. Blending gasoline and diesel fuels with biofuels enables additional annual saving contributions on a continuous basis through this time frame, while hydrogen uptake completes the picture most notably after 2040.

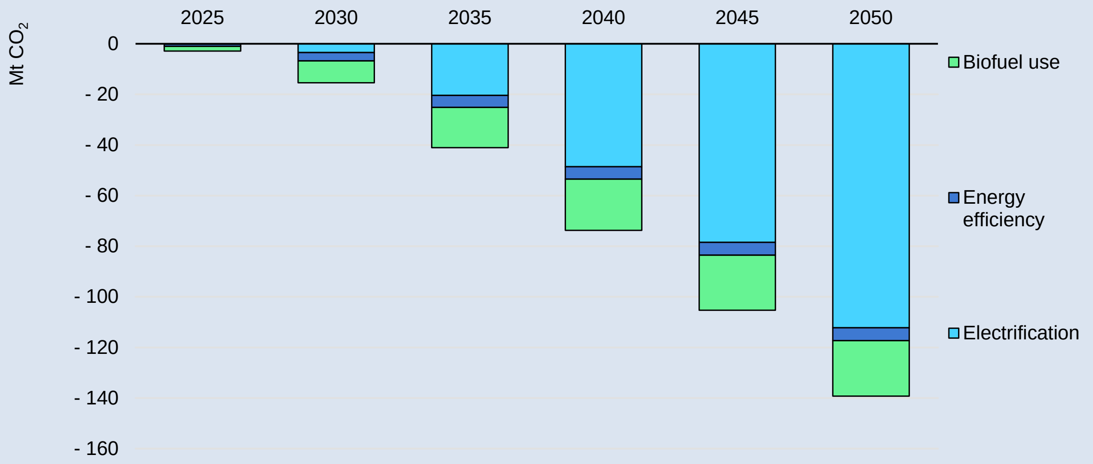
In relative terms, Indonesia could have a higher decarbonisation rate, with emissions decreasing by 70% in the APS compared to in the STEPS. The cars and two- and three-wheelers subsectors account for most of the decrease. The two- and three-wheelers subsector could experience rapidly reducing emissions from 2025. The cars subsector could reach peak emissions in mid-2030, with a rapid decline thereafter owing to the penetration of EVs in the market and a sales ban for conventional or ICE cars by 2050. Emissions due to trucks could have a much slower decline, as electric and fuel cell electric trucks remain relatively expensive until close to mid-century.

Box 2.2 Transport emissions in Indonesia

Indonesia's transport sector (including road, rail, shipping and aviation) accounted for one-third of the country's final energy consumption and around 40% of CO_2 emissions from final energy consumption in 2021. Almost 90% of CO_2 emissions (120 Mt CO_2) in the transport sector, as well as 90% of oil demand, is from road transport. Two- and three-wheeled motorbikes are the preferred transport mode for Indonesians. At 325 motorbikes per 1 000 inhabitants, the ownership rate is double that in India and more than triple the global average. Car ownership in Indonesia is significantly lower, with about 40 cars per 1 000 inhabitants or a quarter of the global average.

In the APS, income growth spurs the preference for, and accessibility of, car ownership over motorbikes, in line with trends observed in many emerging economies. Ownership of motorbikes and other two-/three-wheeler vehicles increases by almost 15% by 2030, but peaks just before 2040 and then begins to decline. However, car ownership jumps to over 75 vehicles per 1 000 people by 2030 and almost 170 cars per 1 000 inhabitants by 2050, multiplying the total stock of passenger cars by more than fivefold compared to 2021 levels.

Enablers of decarbonisation in Indonesia's whole transport sector by measure, Announced Pledges Scenario versus Stated Policies Scenario, 2025-2050



Note: The figure pertains to the entire transport sector, which includes road transport as a subsector. Some additional CO_2 emissions reductions are also generated in the transport sector through avoided demand for mobility and freight transport as well as fuel switching to hydrogen. The graph shows annual CO_2 emissions savings. It includes direct and indirect CO_2 emissions.

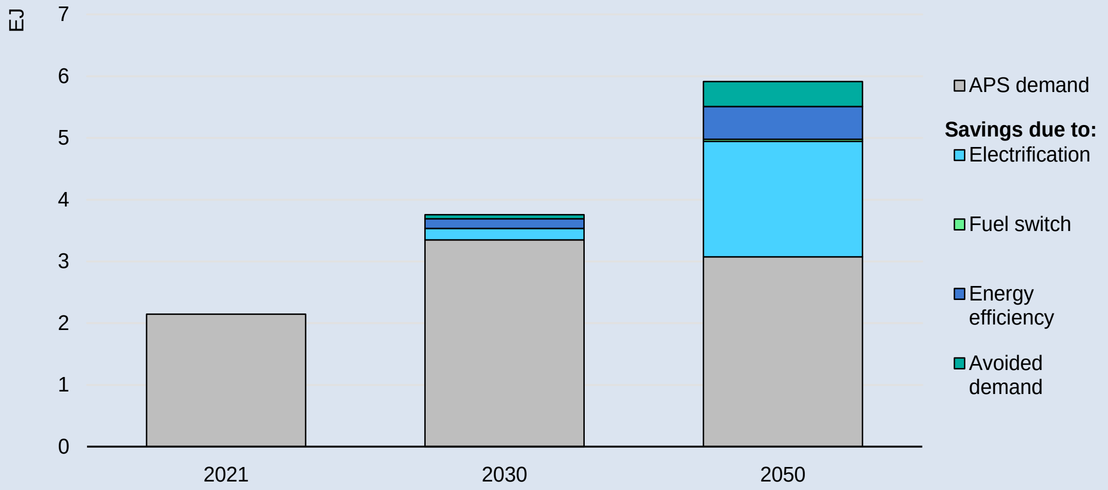
Source: Adapted from IEA (2022), An Energy Sector Roadmap to Net Zero Emissions in Indonesia.

CO_2 emissions due to passenger cars rise rapidly until around 2035 in the APS, owing to there being more cars on the road and continued sales of ICE vehicles. The share of EVs in passenger vehicle sales ramps up only in the 2030s. By 2050, sales of new ICE vehicles will be coming to an end.

The combination of energy efficiency improvements, biofuel blending and especially increasing penetration of EVs drives CO_2 emissions down in the passenger car segment by 2050 in the APS. Biodiesel blending rapidly increases due to the truck subsector. This enables plateauing of CO_2 emissions around 2030. Beyond 2030, the combined effect of increasing electrification of smaller trucks and continued increases in biodiesel use is enough to drive down emissions to almost 20% compared to in 2021, despite an almost tripling in the number of trucks.

In total, Indonesia's entire transport sector can save 140 Mt CO_2 annually by 2050 in the APS compared to the STEPS. Most savings come from transport fleet electrification. This electrification is boosted by the rising penetration of EVs that helps to cut emissions, but the effect becomes more visible after 2030 owing to the slow turnover of the vehicle fleet.

Total annual final energy consumption and demand savings by mitigation measure in the transport sector in Indonesia, Announced Pledges Scenario versus Stated Policies Scenario, 2021-2050



Source: Adapted from IEA (2022), An Energy Sector Roadmap to Net Zero Emissions in Indonesia.

Final energy consumption of Indonesia's transport sector by 2050 would be almost three times as high without increased energy efficiency gains, electrification, avoided demand and other fuel switching relative to 2021 levels. In the transport sector, fuel economy standards introduced by 2025 and accelerating electrification can avoid over 0.35 EJ of oil demand by 2030. By 2050, efficiency gains and electrification can save 2.4 EJ of annual energy demand, while increased use of public transport contributes another 0.4 EJ of savings.

Source: IEA (2022), An Energy Sector Roadmap to Net Zero Emissions in Indonesia.

Existing policies for road transport decarbonisation

Targets, policies and regulations will be needed to achieve an APS-aligned development of road transport in the selected emerging economies. These policies will shape the technological development of different powertrains and modes. They will also influence the decision making of consumers in the purchase of vehicles. A large set of policies have already been implemented in those major emerging economies that help to limit the growth of CO_2 emissions. These can be grouped into three categories: regulation (including standards and mandates), incentives and informational measures.

The first category includes, for example, regulations that mandate a certain share of sustainable biofuels such as bioethanol or biodiesel in the gasoline and diesel fuel mix or standards around the fuel economy of a vehicle. Incentives can range from subsidies and tax credits for the purchase of an EV to fuel excise taxes and public investment in biofuels production. Informational measures focus on programmes that either facilitate co-operation and knowledge sharing among companies and research institutes or information campaigns such as spreading awareness on the benefits of e-mobility.

Table 2.1 Road transport policy landscape in the selected major emerging economies

Category	Policy instrument	Brazil	China	India	Indonesia	Mexico	South Africa
Regulations, including standards and mandates	Biofuel blending mandates	✓		✓	✓		✓
	Fuel economy standards		✓	✓		✓	
	Emissions standards	✓	✓	✓	✓	✓	
Incentives	Charging standards	✓	✓	✓	✓		
	Zero-emission vehicle (ZEV) mandates		✓				
	Fiscal incentives for EVs	✓	✓	✓	✓	✓	
	Fiscal incentives for modal shift	✓	✓	✓	✓	✓	
	Fuel taxes / carbon pricing	✓	✓	✓	✓	✓	✓
	Public investment in biofuel	✓	✓		✓		✓
	Fiscal incentives for scrapping old vehicles		*	✓			
Information	Information and education	✓	✓	✓	✓	✓	✓

* Some fiscal incentives for scrappage schemes exist in China but are determined and implemented at provincial and city level. National policy encourages local governments to put scrappage schemes in place if they have the capacity.

Note: "✓" indicates a country has at least one official policy that is either partially or fully implemented in this category in the current policy landscape (early 2023). An interactive version of the table, including details on all policies in each category, can be found online.

Given the projected energy demand growth in the STEPS (as illustrated in the previous section), energy efficiency in the road transport sector is a key enabler for decarbonisation. Fuel economy standards are important policy instruments that governments put in place to promote vehicle efficiency improvements. In addition to increasing the fuel efficiency of conventional ICE vehicles, such standards can also accelerate the adoption of ZEVs[8], if set at sufficiently stringent levels.

Several of the selected emerging economies have adopted fuel economy standards for cars and light commercial vehicles. China and India developed standards for heavy-duty vehicles. China implemented a standard for two- and

[8] A ZEV is a vehicle that does not emit tailpipe gas or other pollutants. It can be, for example, a battery or fuel cell electric vehicle.

three-wheelers, while India announced the application of fuel consumption standards for two- and three-wheelers from April 2023.

Nevertheless, these standards are not yet homogeneously implemented across countries or subsectors. For example, India has implemented fuel economy standards for cars, with the CO_2 emissions target decreasing from 130 g CO_2/km in 2017 to 113 g CO_2/km in 2022. However, no tightening of these standards has so far been announced or legislated. Brazil, Indonesia and South Africa have not implemented any fuel economy standards in the road transport sector. This is an important policy gap.

Table 2.2 Fuel economy standards in the selected major emerging economies

Mode	Brazil	China	India	Indonesia	Mexico	South Africa
Cars	*	✓	✓		✓	
Trucks		✓	✓			
Two- and three-wheelers		✓	**			

* Since 2012, Brazil has introduced the possibility for manufacturers to receive a discount from a tax on industrialised products through the Inovar-Auto programme (now replaced by Rota 2030), which, in its impact and function, comes close to a fuel economy standard.

** India's Ministry of Road Transport and Highways has announced implementation of fuel consumption standards also for two- and three-wheelers, applicable from 1 April 2023.

Note: "✓" indicates a country has at least one official policy that is either partially or fully implemented in the current policy landscape (early 2023).

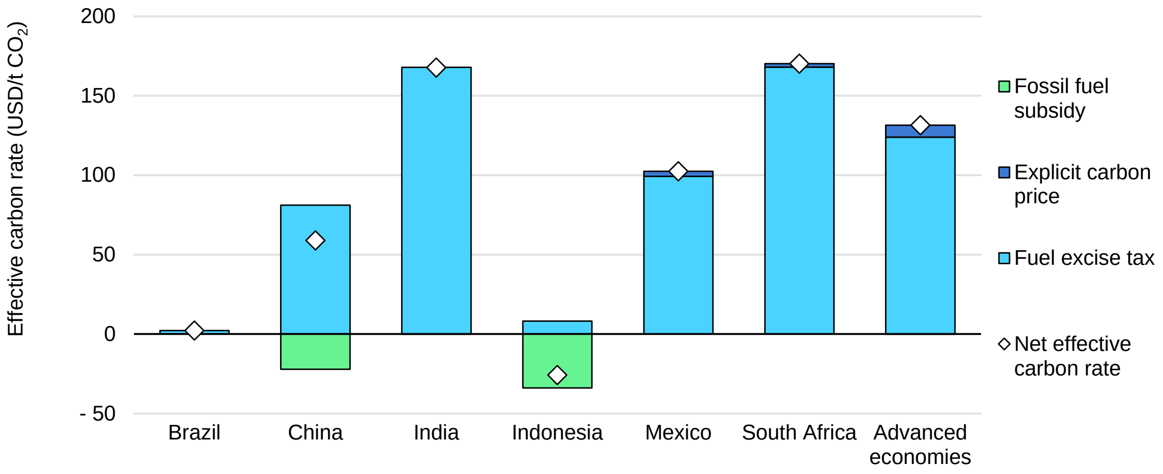
Fuel excise taxes and carbon pricing are also instruments established and used in the transport sector of all the selected emerging economies. Combined with measures such as revenue generation, these can incentivise more efficient fuel consumption. Taking these together with existing fossil fuel subsidies, an effective carbon rate (i.e., an effective cost per tonne of CO_2) can be estimated.

India has the highest effective carbon rate in the transport sector among the selected emerging economies. This is driven exclusively by fuel excise taxes. The Government of India levies the Basic Excise Duty (BED) on some oil and gaseous products. Importantly, it combines this with a so-called Special Additional Excise Duty (SAED) and an additional excise duty on road and infrastructure. Both apply in addition to the basic excise duty on gasoline and diesel fuels for road transport. In combination, these duties amount to a significant level of taxation in comparison to the other selected emerging economies and advanced economies.

South Africa applies similar duty levels with its General Fuel Levy (GFL) and the Road Accident Fund (RAF) levy, both of which apply to gasoline and diesel transport fuels. To illustrate the scale of these levies, the revenues raised by the General Fuel Levy amounted to about 6% of total tax revenues in 2019/20.

In contrast, while Indonesia does apply a set level of fuel excise tax, its effective carbon rate is negative given the high level of fossil fuel subsidies for transport fuels.

Figure 2.7 Effective carbon rates in road transport, 2021



Source: Reproduced from OECD (2022), Pricing Greenhouse Gas Emissions: Turning Climate Targets into Climate Action.

Another approach to reduce fossil fuel consumption in transport is the blending of gasoline and diesel with biofuels. Originally promoted to reduce countries' oil (import) dependency and enhance domestic energy security, biofuels emerged as an important option to reduce CO_2 emissions of conventional ICE vehicles. Bioethanol and biodiesel are the two most common biofuels in commercial use. Bioethanol acts as a blending agent with gasoline and is derived from plant starches and sugars (e.g., sugar cane). Biodiesel is blended with conventional diesel and produced from sources such as new or used vegetable oil or animal fats.

Brazil[9] and Indonesia have developed strong incentives by means of biofuel programmes and mandates. Governments that choose to support introducing biofuels in their transport sector should actively address possible trade-offs with sustainable development goals, including avoiding conflicts at local level with other uses of land, notably for food production and biodiversity protection. Advanced biofuels, based on non-food crops and agricultural residues, can present an attractive alternative to conventional biofuels (e.g., bio-oils from palm oil), and should be promoted.

[9] Brazil has one of the longest experiences globally with biofuels with its National Programme for Biodiesel Production and Use (PNPB) and RenovaBio.

Since 2019, Indonesia has successfully implemented its biofuel blending policy, with 30% biodiesel and 20% bioethanol blending targets by 2020 and 2025, respectively. Plans to increase the biodiesel blending target to 40% in mid-2021 have been delayed to 2025 owing to funding difficulties. In addition, the bioethanol target may be out of reach, as the uptake of ethanol blending remains marginal.

Financially, Indonesia's biofuels policy is supported with allocated government funding, as well as through providing government loans at below-market interest rates for the development of biofuel palm oil plantations. Support should be squared with stringent sustainability criteria to avoid trade-offs with other sustainable development goals. With its Roadmap for Ethanol Blending and its National Policy on Biofuels, India has also laid the groundwork for increasing its blending mandate to 20% ethanol blending by 2025 and 5% biodiesel blending by 2030.

Vehicle fleet electrification is arguably the most effective way to mitigate CO_2 emissions in the road transport sector. A comprehensive policy framework is therefore required to support the supply of and demand for EVs, as well as to provide the necessary charging infrastructure. This includes fiscal incentives such as subsidies and tax credits to produce EVs, as well as for EV purchase, investments for the buildout of charging infrastructure and charging standards. The selected emerging economies, notably China, have developed and deployed fiscal incentives, but limited fiscal leeway has hampered development in many of these selected major economies.

India has implemented strong incentives for EV production and uptake. So-called production-linked incentive (PLI) schemes put forward USD 3.5 billion for domestic manufacturing of EVs and another USD 2.5 billion for large-scale advanced battery manufacturing. This is combined with the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) II programme, launched in 2019 and now extended to 2024. This programme provides USD 1.4 billion by means of direct subsidies for EV uptake. It has been particularly successful in incentivising the uptake of electric two- and three-wheelers and buses, the latter by means of bulk procurement programmes partially financed by FAME II. An additional incentive for battery EVs is provided through a decreased Goods and Services Tax (GST) of 5% (instead of 18-25%) when purchasing such vehicles. A range of state-level subsidies to lower the purchase cost of EVs complements these incentives.

In Indonesia, fiscal incentives for EV uptake are not as developed as in India but have recently received greater attention. To boost the demand for EVs, the government recently decided to exempt EVs from the luxury tax (normally around 15-95%, depending on the engine) while demanding a lower tax rate for hybrid vehicles. Discussions are taking place on introducing further incentives or subsidies for two-wheelers. Indonesia has also recently legalised the conversion of conventional two- and three-wheelers to electric powertrains in public repair shops. This could be an important enabler for the rapid electrification of two- and three-wheelers. Slow uptake of this service so far is mainly related to a relatively high price for the powertrain conversion at about USD 1 000 (IDR 15 million).

In addition to fiscal incentives for EVs, public investment into charging infrastructure and charging standards with standardised guidelines, definitions and building codes for the charging infrastructure of EVs is a crucial precondition for large-scale buildout of charging stations.

For example, the Indian government is allocating USD 130 million for public charging infrastructure through its FAME II programme and aims to install almost 3 000 charging stations throughout the country. In addition, it also passed charging standards in 2019 by integrating the target of up to 20% of parking spaces for EV charging facilities in its building code for Electric Vehicle Supply Equipment (EVSE) building code.

In many of the selected emerging economies, public investment into charging infrastructure and standardising EV charging lag behind. This constitutes another important policy gap that needs addressing if announced pledges and net zero targets are to be achieved.

Cost-effective abatement solutions

Identifying the cheapest and most potent CO_2 reduction measures is an important exercise for policy makers to adequately prioritise policy support at a given time. This will also keep the costs of clean energy transitions as low as possible, especially in times of exceptionally high energy prices. Such policy support can take the form of technology-specific support such as tax credits or grants, and broader instruments such as a carbon price.

For India and Indonesia, marginal abatement cost curves (MACCs)[10] of powertrain switches in cars,[11] trucks, and two- and three-wheelers in the APS from 2022 to 2050 have been created and compared to the STEPS. Computing such MACCs enables policy makers to identify the largest and cheapest CO_2 abatement levers that policies should focus on for effective policy action. It also points out those measures that are not yet cost-effective in an APS pathway and therefore require additional policy support to incentivise their deployment and resulting cost decrease.

[10] These curves show the cost of reducing one more metric tonne of CO_2 with a given abatement solution.
[11] In this section on cost-effective abatement solutions, the category “cars” refers to personal light-duty vehicles only and does not contain light commercial vehicles as elsewhere in this report.

As becomes evident in the MACCs below, due to incrementalism and inertia in the system, some powertrain switches are also happening in the APS despite not being cost-effective. Furthermore, by taking the entire 2022-2050 timeframe and comparing it to the STEPS, the MACCs consider future cost developments and switches from one powertrain to the other annually. This is to demonstrate whether an abatement solution is cost-effective over the entirety of this time frame (rather than for a single point in time) when implementing announced policies and ambitions (APS) compared to stated policies. Moreover, it allows computing cumulative emissions savings by abatement lever without double counting, which is important for understanding the scale of a given abatement lever to achieve the APS pathway.

The scope of emissions in the MACCs is tailpipe emissions – in other words, direct CO_2 emissions. This underlines the importance of a parallel and swift power sector decarbonisation in line with the APS. Only then can certain abatement levers such as a switch to EVs fully realise their decarbonisation potential as depicted in this section.

India

Transitioning road transport in India on an emissions and fleet development pathway in line with its announced policies and ambitions, as modelled in the APS, could be a cost-effective undertaking. It has a total potential saving of USD 200 billion from 2022 to 2050.

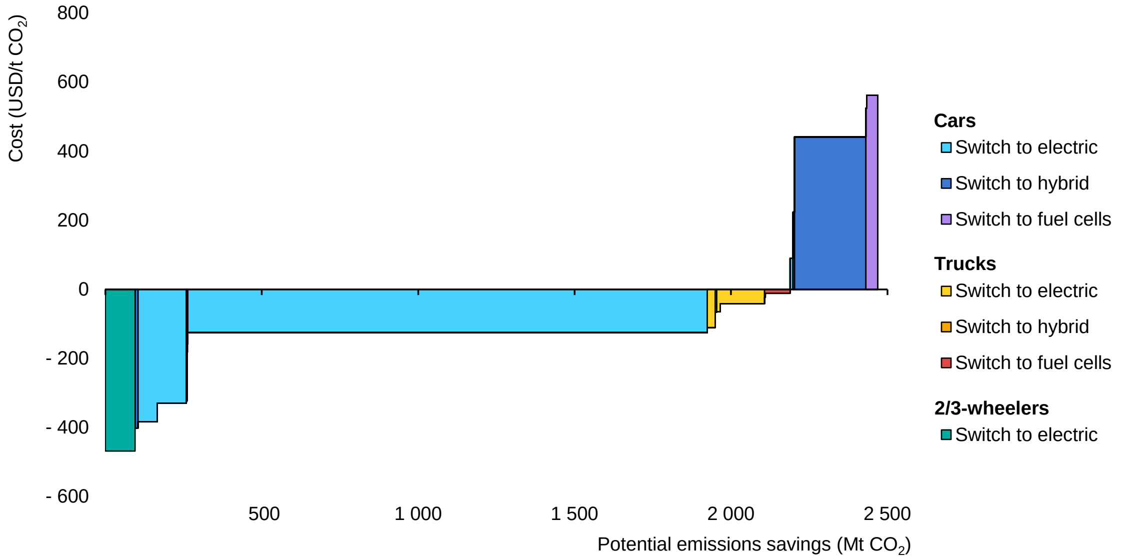
Powertrain switches – especially from conventional ICE vehicles to EVs – have the potential to save an additional 2.5 Gt CO_2 of cumulative emissions[12] at an average marginal abatement cost of -USD 80/t CO_2 in the APS compared to the STEPS.

The analysed powertrain switches could be responsible for more than 60% of cumulative emissions savings in road transport in India, with electrification driving most of the savings. This major role for electrification in driving CO_2 emissions reductions underlines the importance of a rapid decarbonisation of India's power sector. Outside the scope of the MACC analysis, another 1.5 Gt CO_2 in emissions savings could be triggered through fuel economy improvements in the remaining stock of vehicles, powertrain switches to EVs and FCEVs in vans and buses, as well as using biofuels. By far most CO_2 emissions in India's road transport sector could be abated through powertrain switches in cars, followed at some distance by trucks, and two- and three-wheelers. This is unsurprising given the existing large stock and the expected explosive growth in the number of cars on India's

[12] The boundaries for emissions in the MACC analyses for India and Indonesia are tailpipe emissions, to ensure equal treatment among powertrains.

roads, especially from 2025. In the APS, the stock of cars is projected to increase by a factor of 6 by 2050 (relative to 2022), with the number of trucks more than doubling, and the number of two- and three-wheelers almost doubling.

Figure 2.8 Selected CO_2 abatement costs in India's road transport sector in the Announced Pledges Scenario, 2022-2050



Note: This MACC shows the abatement costs and cumulative emissions savings of the entire car, truck, and two- and three-wheeler vehicle fleet in India in the APS compared to the STEPS for the time frame 2022-2050. It is not a comparison of 2050 with 2022 but considers powertrain switches and cost developments annually for the entire time frame. It focuses exclusively on powertrain switches from conventional engines to hybrid, plug-in hybrid, battery and fuel cell EVs. Switches to plug-in hybrid and battery electric are both allocated to "Switch to electric", which explains why there are two different costs associated with a "Switch to electric". Powertrain switches with an emissions savings potential of below 1 Mt CO_2 are excluded. The figure shows direct carbon dioxide emissions. Hence the emissions do not align with the "well-to-wheel" framework for accounting for full fuel-cycle emissions, with implications for all fuels. A recent IEA report analyses the well-to-wheel greenhouse gas emissions, demonstrating that in 2019 battery electric light-duty vehicles had the lowest well-to-wheel greenhouse gas emissions in all segments. For India, the electricity carbon intensity needs to be lower than 700-750 g CO_2/kWh for the net impact of electric vehicle deployment to be positive.

Electrification could drive most of the emissions savings in the APS. For trucks, significant savings could also come from switching to fuel cells. Switching ICE cars to battery electric in India could abate an additional 1.7 Gt CO_2 compared to the STEPS at an abatement cost of around -USD 120/t CO_2, as battery EVs experience a rapid reduction in costs and become cost-effective quickly. This could lead to cost savings of USD 200 billion, just for this powertrain switch.

Other switches to electric in India involve cars with hybrid and compressed natural gas engines switching to battery electric powertrains, which could be achieved at even higher negative abatement costs than for conventional engines. While more than 200 Mt CO_2 in additional emissions savings could also come from ICE cars switching to hybrid powertrains[13] (combination of an ICE and a small electric powertrain) due to the slightly better carbon footprint, this can be realised only at a significant abatement cost of more than USD 400/t CO_2.

Despite lower running costs, this high cost reflects the higher investment cost for hybrid powertrains than ICE cars. This does not decrease significantly in the APS but saves only a relatively small amount of emissions compared to the STEPS. In the two- and three-wheelers subsector, the almost 100 Mt CO_2 in additional emissions savings compared to the STEPS could be delivered at a cost saving of more than USD 450/t CO_2, as electric two- and three-wheelers in India are already cheaper than those powered by ICEs and will continue to become cheaper in the future.

Among the trucks (medium- and heavy-freight trucks) subsector, electrification, followed by fuel cell use, could be a significant abatement lever in India – albeit triggered at a later point in time than for cars. Assuming announced policies and ambitions are implemented in full and on time, shifting heavy-freight trucks from diesel ICEs to electric powertrains could, for example, save around 140 Mt CO_2 at a cost saving of USD 40/t CO_2 over the time frame of 2022-2050. Overall, most of the additional emissions reductions in the APS compared to the STEPS in India's trucks sector are being driven by fuel economy improvements and a modal shift in freight.

Indonesia

In Indonesia, powertrain switches in cars, trucks and two- and three-wheelers have the potential to save an additional almost 1.2 Gt CO_2 of cumulative emissions from 2022 to 2050 in the APS compared to the STEPS. This reflects the significantly smaller road transport stock and absolute emissions from the sector compared to in India.

However, the additional savings could be realised only at an average marginal abatement cost of USD 35/t CO_2, translating to a total cost of about USD 40 billion. Especially for cars, additional support for certain powertrain switches – beyond the policy support and cost reductions already modelled in the APS – will be required to make these switches cost-effective. Subsidies, loan facilities below market prices to lower the upfront investment cost, or pricing of more carbon-intensive powertrains could help in this direction (the financing section in Chapter 3 lays out the financing challenges and opportunities in more detail).

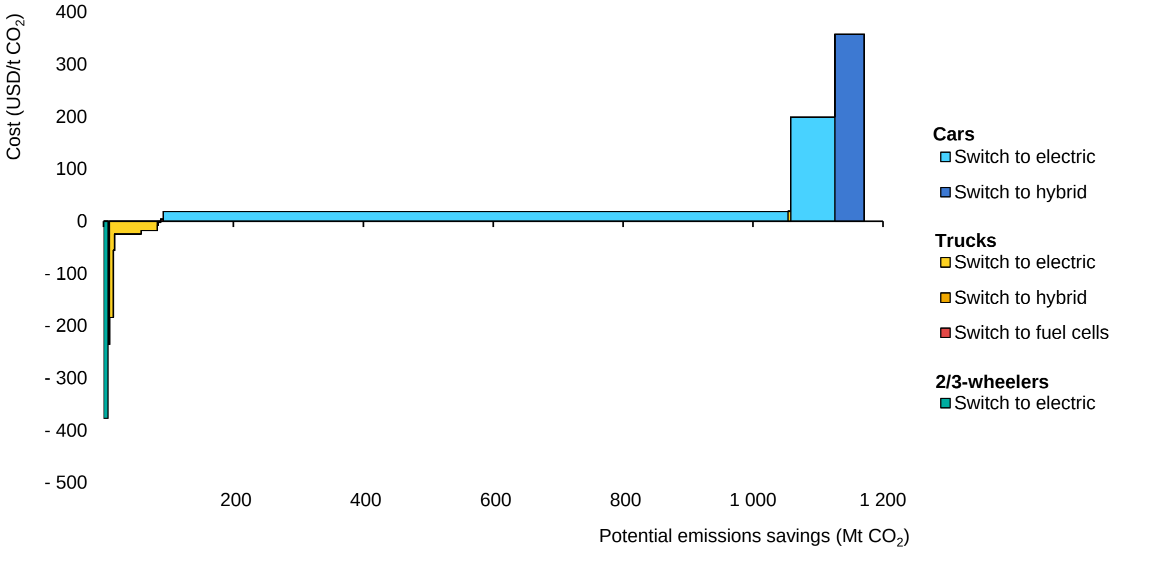
[13] This should not be confused with a plug-in hybrid, which is classified in this report as an electric powertrain, as outlined in the notes on the India and Indonesia MACCs.

Overall, the analysed powertrain switches could be responsible for most of the cumulative emissions savings in road transport in Indonesia in the APS, with direct electrification alone driving about 1 Gt CO_2 in savings. Also outside the scope of the MACC analysis for Indonesia, the remaining emissions savings in the APS are driven by fuel economy improvements in the remaining fleet of vehicles, powertrain switches in vans and buses, and the use of biofuels.

Most CO_2 emissions in Indonesia's road transport sector could be abated through powertrain switches in cars. The car fleet is projected to increase fivefold by 2050, while the number of trucks is projected to double, and the number of two- and three-wheelers is projected to grow by slightly more than a third.

Population growth in the APS in Indonesia is similar in relative terms to that in India. Therefore, the difference in the truck and two- and three-wheeler growth rates between India and Indonesia can be explained through geographic differences. Indonesia relies more on maritime freight transport and a higher usage of light commercial vehicles for last-mile delivery compared to commercial two- and three-wheelers in India. A slightly lower economic growth rate in Indonesia is another factor.

Figure 2.9 Selected CO_2 abatement costs in Indonesia's road transport sector in the Announced Pledges Scenario, 2022-2050



Note: This MACC shows the abatement costs and cumulative emissions savings of the entire car, truck, and two- and three-wheeler vehicle fleet in Indonesia in the APS compared to the STEPS for the time frame 2022-2050. It is not a comparison of 2050 with 2022 but considers powertrain switches and cost developments annually for the entire time frame. It focuses exclusively on powertrain switches from conventional engines to hybrid, plug-in hybrid, battery and fuel cell EVs. Switches to plug-in hybrid and battery electric are both allocated to "Switch to electric", which explains why there are two different costs associated with a "Switch to electric". Powertrain switches with an emissions savings potential of below 1 Mt CO_2 are excluded. The figure shows direct carbon dioxide emissions. Hence the emissions do not align with the "well-to-wheel" framework for accounting for full fuel-cycle emissions, with implications for all fuels. A recent IEA report analyses the well-to-wheel greenhouse gas emissions, demonstrating that in 2019 battery electric light-duty vehicles had the lowest well-to-wheel greenhouse gas emissions in all segments.

Similar to India, direct electrification in the APS is the main emissions reduction lever across all three analysed subsectors, with fuel cell powertrains for trucks playing a less important role. For the car subsector, an additional almost 1 Gt CO_2 could be saved by 2050 compared to the STEPS at a marginal abatement cost of around USD 20/t CO_2. Battery electric personal vehicles experience a rapid reduction in costs also in Indonesia. However, this is not as steep as in India due to significantly higher running costs, with higher electricity prices in Indonesia, a slower decline in the purchase price of EVs and a slightly higher cost of capital.

An additional more than 100 Mt CO_2 in emissions savings by 2050 in the APS could also come from switching ICE cars to plug-in EVs (combination of an ICE with a battery electric powertrain that needs to be charged; in the MACC allocated to "Switch to electric") and to hybrid powertrains (combination of an ICE and a small electric powertrain that does not need to be charged externally). However, this could be realised only at significant abatement costs of USD 200/t CO_2 and around USD 350/t CO_2, respectively.

In the two- and three-wheelers subsector, only around 10 Mt CO_2 in additional emissions savings by 2050 in the APS compared to the STEPS could be realised. However, this is at a highly negative abatement cost due to Indonesia's significantly smaller fleet of two- and three-wheelers than India's and an already large transition from ICE two- and three-wheelers to electric powertrains in the STEPS.

The additional emissions reduction potential for the truck subsector in the APS is of similar magnitude to India when taking the overall smaller truck fleet in Indonesia into account. Switches to electric and plug-in electric powertrains drive this potential. Shifting medium- and heavy-freight trucks from diesel ICEs to electric powertrains could save around 60 Mt CO_2 at a marginal abatement cost of -USD 20/t CO_2 over the time frame 2022-2050. Only a minor share in the truck's subsector is realised through FCEVs in Indonesia.

Box 2.3 Critical minerals and the EV supply chain

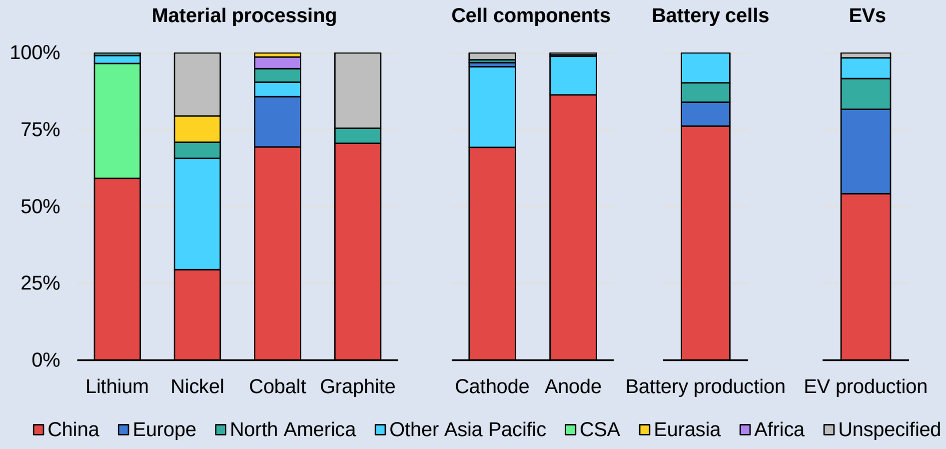
Clean energy transitions in road transport require a strong focus on the supply of critical minerals such as copper, cobalt, nickel, lithium, rare earth elements and aluminium. As clean energy transitions accelerate, demand for critical minerals is set to soar.

In the APS, demand for critical minerals for clean energy technologies is 2.5 times higher by 2030 than in 2021 and quadruples by 2050, with demand rising especially for lithium, cobalt, nickel and graphite. EVs and battery storage are the biggest drivers of this future mineral demand, followed by electricity networks. For example, EVs use around six times more minerals than conventional vehicles, with the difference coming particularly from battery packs.

As the dependence of the road transport sector on critical minerals grows, so too will the importance of securing adequate supplies of sustainable and affordable minerals. With rising mineral prices – as has happened in the past 2 years – critical minerals contribute to an uptick in the total cost of clean energy technologies, reversing a long-standing trend of cost reductions. In addition to volatile prices for critical minerals, the global EV battery supply chain is highly concentrated, which can exacerbate supply chain risks.

The extraction of key minerals is often dominated by a single country or region, for example: graphite (China, 79%), cobalt (Africa, 76%), nickel (Other Asia Pacific, 66%), rare earth elements (China, 57%) and lithium (Other Asia Pacific, 56%). In the downstream supply chain, the situation is often even more concentrated geographically, with China dominating.

Geographic distribution of the global downstream EV supply chain



Note: CSA = Central and South America.
Sources: IEA (2023), Energy Technology Perspectives 2023; IEA (2022), Global EV Outlook 2022.

Getting the prices for critical minerals down and ensuring robust and resilient mineral supplies will be crucial for achieving clean energy transitions in road transport. Greater investment in new mines and refineries, and collaboration between producers and users, will be critical to meet the growing demand for critical minerals while reducing costs. Technological innovation to substitute or reduce the quantity of certain minerals in batteries will also be important. Reuse and recycling can address supply bottlenecks and reduce overall mineral demand, while mitigating some of the adverse environmental and social impacts associated with extraction and processing of critical minerals.

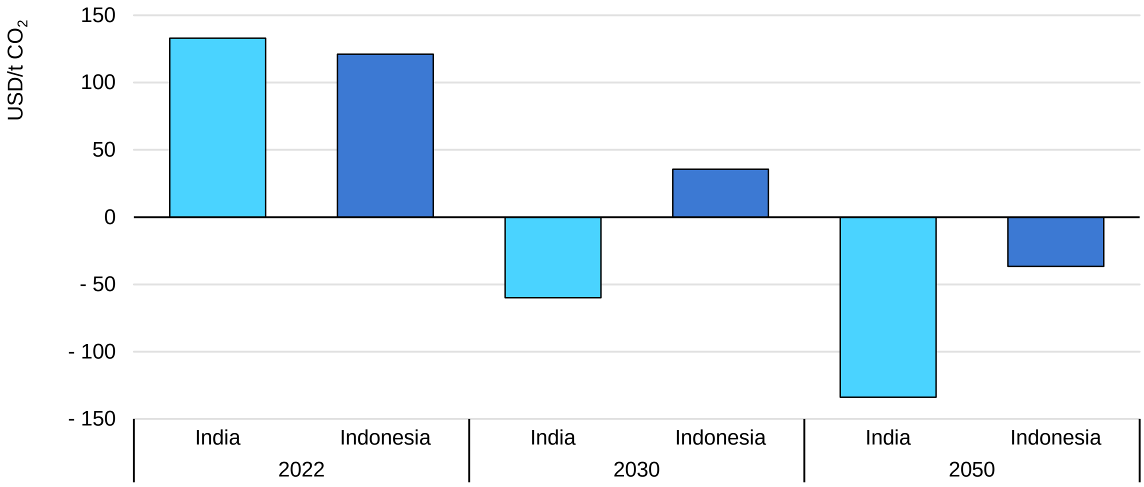
Sources: IEA (2023), Energy Technology Perspectives 2023; IEA (2022), World Energy Outlook 2022; IEA (2022), World Energy Investment 2022; IEA (2022), Global Electric Vehicle Outlook 2022; IEA (2021), The Role of Critical Minerals in Clean Energy Transitions 2021.

Comparison of marginal abatement costs

In the road transport sector, India and Indonesia have significant additional emissions reduction potential in the APS compared to the STEPS, albeit at different costs. Realising the 2.5 Gt CO_2 in savings in India until 2050 could come at cumulative savings of almost USD 200 billion. In Indonesia, it would cost more than USD 40 billion to abate 1.2 Gt CO_2. In addition to differences in the existing fleet, economic structure and geography, a main reason for this is the difference in the development of abatement costs over time – especially for powertrain switches from ICE cars to EVs, which are responsible for most of the emissions savings.

India and Indonesia have similar marginal abatement costs for the powertrain switch to electric. However, India could experience a more rapid fall in the abatement cost due to a faster decrease in the purchase price, driven by the development of domestic models for battery EVs. This comes on top of slightly lower costs of capital (which translate into cheaper loans for car purchases) in India (see Chapter 3) and higher running costs for battery electric cars in Indonesia due to higher electricity prices, especially for residential charging.

Figure 2.10 Marginal abatement cost for the switch of one conventional car to a battery electric powertrain over time in India and Indonesia in the Announced Pledges Scenario, 2022-2050



IEA. CC BY 4.0.

Note: This graph shows the marginal abatement cost of switching one conventional car to a battery electric powertrain over time in the APS, compared to the STEPS. In contrast to the MACCs above, this figure focuses on the powertrain switch for a single vehicle. The boundary for emissions is tailpipe emissions to ensure equal treatment among powertrains.

Additional air quality co-benefits of road transport transitions

Beyond CO_2 emissions reductions, road transport transitions can also generate significant air pollution and associated health co-benefits. Both are significant concerns for emerging economies.

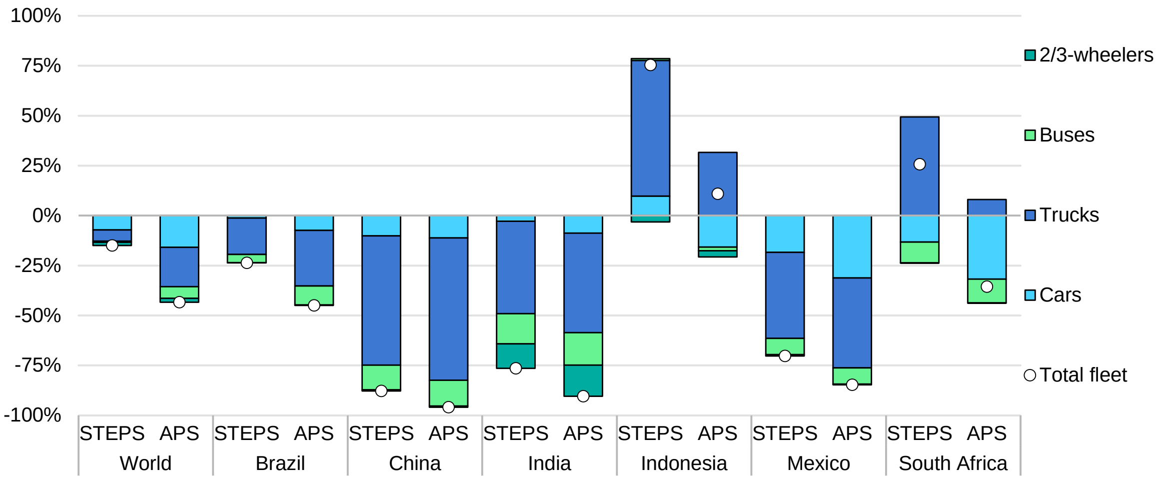
In 2021, ambient air pollution caused 4.2 million premature deaths globally. Almost 2.5 billion people suffered from heavily polluted air, in concentration levels of fine particulate matter ($PM_{2.5}$) of more than 35 µg/m^3. Of these, more than 60% lived in China, India and Indonesia. In China and India, more than 45% and 60% of the respective country's populations were exposed in 2021, significantly above the global level of one-third.

Road transport contributes significantly to air pollution by emitting substantial amounts of tailpipe-related nitrogen oxides (NO_x). Travelling through the atmosphere, these transform into $PM_{2.5}$ through chemical reactions. The sector further causes $PM_{2.5}$ emissions through tailpipe, abrasion of tyres, road wear and road dust suspension. Reducing tailpipe emissions can have direct public health benefits. A major share of emissions occurs in urban areas, as well as close to the ground, thus directly exposing many people to such pollution.

In the selected emerging economies, road transport emitted around 8 Mt NO_x, which was one-third of the sector's global emissions, in 2021. Of this, the trucks subsector caused two-thirds, followed by cars. Globally, NO_x emissions from road transport are set to decrease. In the STEPS, they reduce by 15% globally by 2050 relative to 2021. More ambitious road transport transitions in line with the APS would allow a reduction of nearly 45% over the same period.

Important policies and technology development include vehicle electrification and more stringent emissions standards. China and India are important drivers of this positive development, decreasing NO_x emissions related to road transport until 2050 by at least 75% in the STEPS and around 90% in the APS. Both countries, as well as Brazil and Mexico, substantially reduce emissions due to trucks and buses until 2050, yielding the overall reduction.

Figure 2.11 Change in NO_x emissions related to road transport by 2050 in the Stated Policies Scenario and the Announced Pledges Scenario, relative to 2021



In contrast, Indonesia and South Africa show a strong increase in truck-related NO_x emissions until 2050 in the STEPS, outpacing reduction efforts in other segments. More ambitious road transport transitions could significantly curb the growth in truck-related emissions in both countries and achieve NO_x reductions from the car subsector in Indonesia.

Chapter 3. Implementing road transport transitions

Governments in the selected major emerging economies play a critical role in achieving successful clean energy transitions in the road transport sector. While all analysed countries already have established road transport policies, additional potential exists for enhanced policy ambition and implementation. As economic and population growth drives demand for mobility and freight transport, the selected emerging economies will require functional, reliable, effective, and affordable transport systems.

There is an opportunity to leap-frog the transport model of advanced economies, which depends on fossil fuels and is often dominated by personal vehicles. However, this will require addressing some formidable barriers to enhanced policy ambition and implementing certain key transport policy interventions. Crucially, this will also depend on the governance of the road transport sector, to ensure equal opportunities and access to mobility services for citizens while addressing the decarbonisation challenge.

This chapter discusses the main barriers to enhanced policy ambition in the road transport sector in the selected emerging economies and deep dives into the financing aspects related to the transition. It finishes by laying out six key policy interventions that can help accelerate decarbonisation and development of road transport in these major emerging economies.

Structural barriers to enhanced policy ambition

An important barrier to enhanced policy ambition and implementation in road transport sector decarbonisation is its governance. The inexistence of, or outdated, nationwide medium- and long-term road transport strategies, a lack of clarity in the policy decision-making process and limited capacity, especially in implementing agencies, can slow and restrain effective policy making and implementation thereof.

In the past two decades, the selected major economies have experienced remarkable economic and population growth rates, which naturally pose significant challenges to existing institutional frameworks for critical services (e.g., health, energy and taxation). In addition, as road transport policy making is an area where jurisdictions and competencies are dispersed across different levels of governance and authorities. A lack of co-ordination among national, regional and local agencies, as well as insufficient capacity at implementing agencies (including for enforcement of policies), can create a bottleneck and undermine the effectiveness of policies. A lack of centralised and good-quality data aggravates these problems. Developing periodic, solid and reliable data collection processes in combination with building capacity for the assessment and modelling of road transport development scenarios are key to sound policy making and the development of ambitious, yet realistic, road transport transformation strategies.

Public support is also important in implementing transitions in the road transport sector. As mobility and freight demand grow significantly, designing integrated strategies that ensure the affordability and equity of transport, as well as the acceptability of different transport modes, is crucial.

For example, public transport services need to be organised effectively and provide a safe environment for customers while being affordable. This will enable them to become an acceptable solution to the public and disincentivise the unnecessary use of personal vehicles.

In addition, to avoid social inequalities, removing fossil fuel subsidies or setting a carbon price in the road transport sector needs to be combined with targeted support (e.g., lump-sum payments, improved access to capital, subsidies for EVs and public transport) to vulnerable households.

Limited financial capacity for major capital investments in road transport is another barrier, particularly in emerging economies. This can come in different forms: limited public sector budgets, lack of capital by households, shallow domestic banking systems and limited availability of loans, or high capital costs for financing of transport infrastructure or vehicle purchases.

For example, EVs typically have a significantly higher upfront investment cost (while having lower running costs) than conventional cars. They are therefore more difficult to finance for households that do not have the financial resources or access to cheap financing.

The strengthening of the domestic banking sector and of households' financing conditions, the removal of market distortions and the targeted use of major state-owned enterprises for demand creation are important elements to address such financial obstacles and to channel investments in the right direction. International finance instruments such as overseas development aid, climate finance, multilateral finance and blended finance (including in the form of the successfully agreed Just Energy Transition Partnerships with Indonesia and South Africa) can also be crucial pillars to overcome financing barriers.

Emerging economies can face additional challenges for enhanced policy ambition. Examples include energy security concerns such as the domestic availability of oil while having to rely on imports for EVs and fuel cell vehicles or import dependencies for key parts of a domestic EV value chain. Such concerns deserve careful examination to identify means to reduce dependencies and to leverage international collaboration. Besides, exploiting opportunities in the emerging and growing EV and fuel cell value chains depending on the country's resource, technology and labour capabilities must be taken into account.

By moving faster than others in the manufacturing of EVs, the selected emerging economies have a significant opportunity that can boost automotive exports, contribute to economic and industrial development, and improve productivity.

Financing the transitions

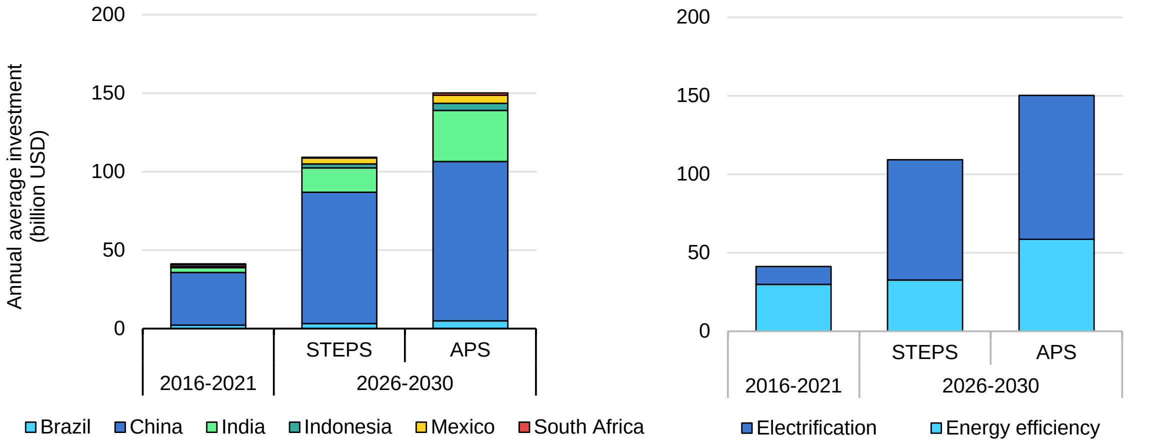
Successfully mobilising investment is central to road transport transitions and to putting the sector in line with the net zero and carbon neutrality targets of major emerging economies.

Annual end-use investment in road transport – including in EVs and vehicle efficiency – in these major emerging economies averaged around USD 40 billion over the period 2016-21. It grew strongly in the last few years, to nearly USD 60 billion in 2021. Leading this investment was an almost tripling in transport electrification spending in 2019-21, with energy efficiency spending remaining relatively stable.

However, more investment is needed. In the STEPS, average annual end-use investment in road transport needs to reach USD 110 billion in the second half of this decade. Then, an additional 40% is needed annually to 2050.

Furthermore, to meet the announced climate targets by the major selected emerging economies, annual investment will need to reach USD 150 billion from 2026 to 2030, and to over USD 230 billion annually by 2050 in the APS. Such a surge would require domestic efforts to strengthen the environment for clean energy investment, as well as international efforts to increase availability of capital for low-carbon mobility in the selected emerging economies.

Figure 3.1 Road transport investment compared to their average annual investment needs, 2016-2021, and in the Stated Policies Scenario and the Announced Pledges Scenario, 2026-2030



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Of the analysed countries, most of the investment continues to occur in China. Nevertheless, investment is set to grow more rapidly in several other selected emerging economies, particularly India and Indonesia.

In the STEPS, average annual road transport investment in 2026-30 grows to around USD 85 billion in China, USD 15 billion in India, and USD 2 billion to USD 5 billion in Brazil, Indonesia and Mexico, while remaining below USD 1 billion in South Africa. This compares to an annual average of around USD 35 billion in China, and up to USD 3 billion in other selected emerging economies during 2016-21. The fastest growth is expected in India and Indonesia – to more than quadruple investment in 2026-30 compared to their average annual in 2016-21.

However, to achieve national climate goals, countries need to ramp up their annual investment to 2030 in the APS: 20% in the case of China (to over USD 100 billion), 40% in Mexico, 50% in Brazil, 80% in Indonesia, doubling in India (to over USD 30 billion) and almost tripling in South Africa.

In terms of area of investment, annual spending on EVs from the six countries needs to grow to USD 90 billion in 2026-30 in the APS, compared to an annual average of USD 10 billion in 2016-21 or around USD 30 billion in 2021. Planned policies are on track to provide 80% of this investment, if fully implemented. A larger gap exists in energy efficiency spending, which needs to double towards 2030 in the APS, but is set to remain at the current level without further policy efforts.

In the long term to 2050, spending on electrification is set to account for an increasingly larger share of the investment in road transport transitions. However, investment in energy efficiency falls in the APS as conventional ICE vehicles are increasingly substituted with EVs. Nevertheless, additional efforts are especially required to incentivise the electrification investment needed over the long term. Without such efforts, most countries will realise only around 60% of the investment in EVs needed for the APS pathway.

Road transport transitions also require investment in charging infrastructure. In addition to investment in public charging infrastructure and associated grid development, average annual spending on private EV chargers in the selected emerging economies needs to increase to nearly USD 40 billion in 2026-30 in the APS. This was less than USD 1 billion annually in 2016-21, with India's private EV charger spending rising to comparable levels to China's (over USD 16 billion), followed by Indonesia (USD 4 billion).

In the overall period to 2050, average annual investment needs for private charging infrastructure doubles to around USD 90 billion in the APS. In the STEPS, spending for private EV chargers is projected to be only around half the levels of the APS in most countries.

The use of low-carbon fuels is another important channel for road transport decarbonisation. Investment in liquid biofuels in the selected emerging economies totalled nearly USD 5 billion annually in recent years, led by Brazil with 70% of the share. Most of the liquid biofuels used are in the road transport sector, though gradually growing shares are set to be used as sustainable aviation fuel and for maritime transport.

In the STEPS, investment in biofuels in the selected emerging economies grows moderately to USD 6 billion by 2030 and further triples by 2050. Investment scales up significantly in the APS, to over USD 30 billion by 2030 and subsequently grows marginally to 2050, with increased investment in advanced biofuels.

Actors and instruments

A variety of actors are involved in shaping the role of finance and investment for road transport transitions. Governments play a critical role in mobilising and enabling clean energy investment. They define the policy framework and market environment for road transport and for sustainable finance, as well as often acting as an important source of finance.

In addition, financial regulators and supervisors can promote sustainable finance by defining or encouraging the adoption of climate change disclosure and risk management standards, providing investment incentives, and shaping rules on debt issuance in support of clean energy transitions. International standard setters, such as the Financial Stability Board, the Basel Committee on Banking Supervision and the International Association of Insurance Supervisors, help set up such disclosure and risk management recommendations and sharing of best practices.

Energy investments in EMDEs generally rely on public sources of finance. These sources include public finance institutions, such as development banks and infrastructure funds, which play important roles in extending credit lines and guarantees to financial institutions and companies, reducing risks and improving bankability of projects.

State-owned enterprises constitute another major source of public financing in EMDEs and are particularly important for investment in regulated networks such as electricity grids. They generally have large stakes in power, oil and gas, and industry.

As elsewhere, clean energy sectors in EMDEs have so far mostly been financed by private finance, including companies, commercial banks, private investors and consumers. Meeting the investment needs to support higher climate ambitions will require an even greater scale-up of private finance.

In the transport sector, most of the future investments in the end-use transition by 2030 – in EVs and EV-related energy efficiency – are expected to come from private sources. These include automobile companies (also known as original equipment manufacturers) and households, but governments continue to play important roles in mobilising capital.

Public financing continues to help de-risk and mobilise investment and support market uptake through public procurement for vehicle fleets. Moreover, it provides grants or guarantees to consumers and enabling infrastructure, such as EV charging stations and mass-transit infrastructure. Compared to sectors such as low-carbon power, direct investment in road transport transitions is more likely to come from domestic sources, as vehicle purchases usually occur locally.

However, international participation can provide important financing support to sustainable transport infrastructure and industry development. For example, the Asian Development Bank had committed over USD 18 billion to India's transport sector as of April 2022. This supports almost 200 projects by means of loans, grants and technical assistance, with a strong focus on infrastructure to improve connectivity and alleviate poverty. Such international support can accelerate the transitions, with a stronger focus on low-carbon mobility infrastructure.

With respect to value chain development for EVs, investment and production capacity from car manufacturers and suppliers are concentrated in advanced economies and China. However, opportunities exist for other selected emerging economies to attract investment from original equipment manufacturers and to expand local manufacturing capacity. In many cases, this will require developing more favourable regulatory frameworks for domestic vehicle manufacturing and addressing challenges related to access to finance and import of key components.

In terms of financing instruments, investment in emerging economies relies heavily on equity financing, while provision of debt is often limited by higher perceived or real default risks, a lack of projects meeting bank lending criteria and shallow local banking systems and credit markets. This means that for emerging economies, the overall cost of capital is often higher than for advanced economies because debt financing is normally cheaper than equity.

In addition to the shallower banking systems and credit markets and the associated currency risk for international lenders, debt providers receive interest payments and have a preferred repayment status in the case of insolvency or default. This translates into a usually lower risk premium for debt investments than equity, thus lowering the cost of capital. Given this difficulty, domestic public and multilateral financial institutions such as the World Bank, its International Finance Corporation or the Asian Development Bank can play an important enabling function in this investment segment by providing debt finance or underwriting debt investments.

However, governments have a responsibility to improve domestic banking systems and associated credit markets. At a micro level, increasing debt financing options such as car loans for consumers, which can help with financing the higher upfront costs of ZEVs, is crucial to facilitate market uptake.

For more nascent technologies required for long-term decarbonisation of the road transport sector, blended finance from development finance institutions such as concessional funds and guarantees plays an important role. Providing such funds and guarantees can help to enable and leverage private investment by de-risking and supporting first-of-a-kind projects in EMDEs. As technologies mature and business models emerge, export credit agencies and larger institutional investors can act as financing sources for larger projects through project financing structures and long-term offtake agreements.

Barriers to scaling up investment

Financing road transport transitions in line with the announced climate ambitions of the major selected emerging economies continues to face barriers. These are often related to cross-cutting policy and regulatory factors, development of capital markets and financing capacity in countries. Strengthening policy frameworks is crucial to address the barriers and scale up investment for transition.

Cross-cutting factors such as clean energy transitions planning, price signalling, market structure and broader governance are important factors for investment decisions. While all the selected emerging economies have implemented some policies to support road transport decarbonisation, this sector has not necessarily been a priority for national emissions reduction strategies.

In addition, the sector may lack holistic, long-term planning with a focus on decarbonising. This could lead to policies that send mixed signals for investment, such as policies aimed at facilitating the uptake of all kinds of vehicles rather than focusing on ZEVs or public transport.

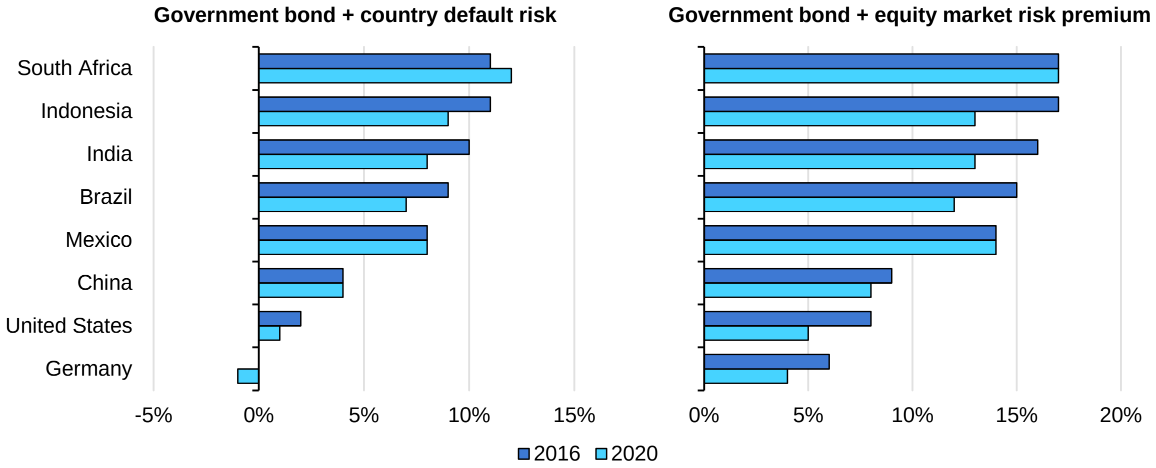
Fossil fuel subsidies are a prominent example of negative price incentives for sustainable transport. Such subsidies tilt the playing field against investment in clean energies, while also constraining fiscal capacity from investing in transition. In addition, challenges related to governance and administration, such as uncertainty or opaque regulation, contractual enforcement, and complexities in licensing and permitting processes especially for private or foreign actors, tend to deter investors. Besides, this increases financing costs and lengthens project development. Furthermore, some EMDEs maintain restrictions on foreign investment, market access and ownership, thus limiting the potential role of international capital.

Higher cost of capital is an important barrier to expanding clean energy investment and improving affordability of transitions in EMDEs. Except for China, the other selected emerging economies face equity financing costs that are two to three times higher than those of Europe or the United States, and debt financing costs that are 7% higher or more. These levels reflect multiple factors including perceived country risks and the maturity of their financial systems.

In addition to higher costs, this translates to greater challenges in accessing debt finance and offering adequate returns on equity, despite abundant global capital. A high cost of capital can have an especially large impact on clean energy investments, which often involve high upfront costs, and which are more sensitive to financing costs.

Global inflationary pressures in 2022 have aggravated this matter, as central banks around the world increased interest rates (with some exceptions, such as China). Higher interest rates mean higher financing costs for governments, corporates and consumers. In addition, inflation increases the costs of raw materials and products, thus requiring more investment.

Figure 3.2 Indicators of cost of capital for debt (left) and equity (right), 2016 and 2020



Note: United States and Germany have been included for comparison purposes.
Source: IEA (2021), The cost of capital in clean energy transitions.

EMDEs tend to have shallower banking sectors and financial markets than advanced economies. This constrains access to capital to fund clean energy transitions. The level of financial sector development varies across countries. Assessed based on the share of private bank credit to GDP and the share of stock market capitalisation to GDP, China and South Africa have better access to finance than the global average. In comparison, Brazil, India, Indonesia and Mexico have shallow financial systems.

Moreover, local banking sectors in EMDEs often lack the capacity and expertise to evaluate the risk and return profile of clean energy projects. This tends to reduce access to capital and increase costs. In addition, debt finance in EMDEs is typically more constrained for consumers, and small- and medium-sized enterprises lack access to formal credit markets, thus increasing their financing costs. This constitutes an important barrier for adopting low-carbon transport solutions, despite improved technology maturity and cost-competitiveness over a vehicle’s lifetime.

In most major selected emerging economies, EV purchases remain a challenge for many consumers in the absence of government support. This is due to the high upfront costs compared to conventional ICE vehicles and the lack of access to cheap financing options such as loans.

Emerging economies are also more likely to face insufficient resources – financial or fiscal – to accelerate the deployment of infrastructure required for sustainable transport. Such infrastructure includes EV charging stations and hydrogen refueling stations, which are crucial for EVs and fuel cell vehicles. Long-tenure debt is often not available from (or to) local banks in EMDEs. For example, loans in Southeast Asia have an average duration of just over six years. This makes it difficult to finance infrastructure that has long operating lifetimes of 20-30 years.

Public finance has a critical role in co-financing and reducing risks, especially for infrastructure investments. However, many EMDEs tend to have limited fiscal capacity due to the inability to raise sufficiently cheap capital through debt issuance on financial markets.

Recommendations for strengthening transitions' financing

In addition to setting clear, ambitious and integrated clean energy strategies for the road transport sector (see the section on key transport policy interventions), removing market and pricing distortions that contravene a scale-up in clean energy investments, such as fossil fuel subsidies, is essential.

Establishing the correct price signals to reflect the full costs of fossil fuels, including phasing out fossil fuel subsidies and gradually introducing carbon pricing to reflect the cost of carbon emissions, is essential to discourage wasteful fuel consumption and incentivise clean energy.

Phasing out fossil fuel subsidies will also help free up fiscal capacity, and carbon pricing can generate revenue to invest in transition measures and enabling infrastructure. While subsidy and market reforms are often politically challenging, strong stakeholder engagement and targeted protection for vulnerable segments of the population can ensure equity and support political acceptability.

Leverage policy and public financing support to accelerate infrastructure development

As infrastructure projects often require high upfront investment and long construction periods, as well as face uncertainties on future revenues, strong policy commitment and involvement of public financing can reduce risks and attract additional private investment. Public-private partnerships (PPPs) can be an important instrument to scale up infrastructure investment.

For example, Indonesia has identified PPPs as an important mechanism to encourage private investment to meet over half of the funding needs for 2020-24 in addressing the country's infrastructure gaps. It has established a comprehensive policy framework and governance structure, to improve the attractiveness of PPPs for private investors through greater transparency and clarity on the process. It also established a dedicated unit for PPP management within the Ministry of Finance. This is supported by several public financing instruments such as PT Sarana Multi Infrastruktur and PT Penjaminan Infrastruktur Indonesia. By these means, Indonesia can provide loans, guarantees and technical assistance, and improve governance and transparency for guaranteed provision.

Strengthen sustainable finance frameworks

Creating taxonomies on sustainable finance and enhanced risk disclosure and assessment can strengthen sustainable finance frameworks. Countries are developing taxonomies to classify activities and assets contributing to clean energy transitions or financial risks associated with climate change and to guide investment, including "green", "carbon-intensive" and "transition" taxonomies.

For example, China issued a Green Bond Endorsed Projects Catalogue, last updated in 2021, to guide financial institutions and corporates on the issuance of green bonds. By 2020, over 70% of green bonds issued in China followed the catalogue.

India launched its sovereign green bonds framework in 2022, earmarking proceeds for environment-friendly projects including clean transportation. The country raised USD 1 billion in its first green bond sale, achieving a lower borrowing cost than for a conventional bond of similar maturity.

Indonesia's 2022 Green Taxonomy is one of the country's first policy attempts to encourage the private sector to prioritise green investments. It employs a traffic light system to indicate an activity's alignment with national environment objectives.

Enhance availability of debt finance and strengthen the domestic banking sector

Making debt finance more accessible to the private sector (including longer-duration loans) through the development of corporate bond markets can play an important role in reducing the cost of capital for clean energy transitions projects. Increasing the availability of car loans to households for purchase of ZEVs is also important. For example, the State Bank of India launched a dedicated programme to support EV purchases, offering a discount of 0.2% for EV loans with a tenure of up to 8 years. It is planning to replace its current car loan programmes with 100% EV car loan programmes by 2030.

At the same time, it is important to strengthen the capacity of the local banking sector – especially with regards to credit appraisals for clean energy projects – to optimise capital allocation in line with clean energy targets. To do so, some countries have established dedicated institutions or instruments.

For example, the Climate Finance Facility (CFF) in South Africa is a specialised lending facility to increase private investment in climate-related infrastructure projects. It supports projects that are commercially viable, but which are unable to attract market-rate capital at scale from local commercial banks by using credit enhancement instruments such as long-term subordinated debt and tenure extension.

Scale up international support for catalysing transitions in EMDEs with limited fiscal resources

Alongside country efforts to achieve transitions, stronger international efforts to channel lower cost and longer-term capital are required. These include enhancing strategic mandates on clean energy transitions for international financial institutions (e.g., multilateral development banks) and increasing the use of blended finance to leverage private capital. These could be complemented with capacity building efforts for local financial markets, with a focus on credit appraisals and risk management for clean energy projects.

The recently agreed Indonesia and South Africa Just Energy Transition Partnerships offer strong examples of international co-operation in financing clean energy transitions in emerging economies and leveraging private capital. While the two partnerships focus on the power sector transition, the model could be expanded to the transport sector.

Key road transport policy interventions

A road transport decarbonisation pathway in line with the APS in the selected major emerging economies requires significantly enhancing existing policies and introducing additional policies in most of the selected countries. Beyond the recommendations for strengthening financing for the road transport transitions, this section lays out six policy areas key to these transitions and provides measures and good practices to facilitate knowledge sharing among countries.

Table 3.1 Summary of key road transport intervention areas and measures for the selected major emerging economies

Intervention area	Measure
General transport policy making	Ensure holistic long-term planning for the transport sector
	Enhance institutional co-ordination across jurisdictional levels
	Avoid fossil fuel subsidies and introduce differential pricing
Public transport and transport demand	Enhance a modal shift to public transport and active mobility
	Decarbonise public transport
Electrification of cars and two-/three-wheelers	Implement demand-side policies to accelerate market demand

Intervention area	Measure
	Implement supply-side policies to increase market availability of EVs
	Strengthen buildout of the EV charging infrastructure
Vehicle efficiency	Adopt and regularly update fuel economy standards
	Develop appropriate and stringent test procedures
	Design fuel economy standards for trucks
Road freight transport	Drive innovation in and deployment of zero-emission freight trucks
	Encourage modal shift and improve logistics
Biofuels	Implement policies to support biofuel uptake
	Promote innovative and sustainable biofuels
Finance	Leverage policy and public financing support to accelerate infrastructure development
	Strengthen sustainable finance frameworks
	Enhance availability of debt finance and strengthen the domestic banking sector
	Scale up international support for catalysing transitions in emerging economies with limited fiscal resources

Strengthening transport policy making

Ensure holistic long-term planning for the transport sector

Robust decarbonisation of the road transport sector requires holistic long-term planning that also involves other modes of transport such as rail, aviation and shipping. A comprehensive and inclusive long-term plan to decarbonise the road transport sector requires aligning transport policy with urban infrastructure and other investment planning, as well as with all stakeholders.

Technology improvements, modal shifts, demand management and effective governance of transport policy are essential components of clean road transport transitions.

Countries should develop an overarching, holistic strategy for transport decarbonisation (e.g., a national transport plan), and should do so in an inclusive manner involving all stakeholders. Such a strategy helps to provide a clear and credible vision for the sector and identifies milestones that need to be achieved against a defined timeline, as well as the policies to enable transitions. Such a national transport plan can enhance transparency and policy predictability for regional and local governments, manufacturers, investors and consumers. This is important for investments in technology R&D and infrastructure, market uptake for low-emission vehicles and ZEVs, and crucially, the political acceptability of road transport transitions.

One example of such a national clean transport plan is South Africa's Green Transport Strategy. It formulates the ambition to build a safe, efficient, reliable and affordable transport system that enables sustainable socio-economic development. It promotes behavioural changes towards sustainable mobility alternatives through information campaigns and investments in low-carbon infrastructure. It also seeks to enhance freight modal shift by setting sub-sectoral targets for the freight sector.

Dedicating a specific section to transport in national long-term climate change mitigation strategies is another possibility to develop a holistic vision for road transport decarbonisation. Costa Rica's National Decarbonisation Plan for 2018-50 identifies transport as an important area for climate action, naming public transport and active mobility schemes, zero-emission cars and a modal shift in freight transport as the first three out of ten opportunities for decarbonisation and setting short- and long-term ambitions for each of them.

Countries could also seek to align strategies to decarbonise the (road) transport sector with national long-term climate targets such as net zero pledges and nationally determined contributions (NDCs).[14] One approach to link these two could be to develop sectoral pathways for (updated) NDCs. While nearly all NDCs mention the transport sector, only 53% of them refer to specific measures to achieve their mitigation targets in the transport sector.

For instance, Bangladesh and Colombia have set unconditional emissions reduction targets for 2030 for their transport sectors, laying out mitigation measures they intend to implement. Colombia aims to mitigate 4 Mt CO_2-eq by deploying 600 000 EVs by 2030. Bangladesh targets a decrease of 3.4 Mt CO_2-eq by 2030 through reducing traffic congestion, improving fuel efficiency and promoting modal shift.

Enhance institutional co-ordination across jurisdictional levels

Implementing comprehensive road transport transitions requires effective institutional co-ordination and collaboration. Road transport is a concurrent policy area in most jurisdictions, and some institutions have responsibilities relevant to transport. Effective co-ordination across topic areas (e.g., transport, energy and environment policy) and across government levels (e.g., national, regional and local) can decrease costs and enhance outcomes.

For instance, many transport ministries traditionally lack knowledge on climate change policies and could benefit from capacity building. Cross-ministerial

[14] NDCs embody the efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve.

co-ordination groups can help with transferring relevant knowledge and integrating it into policy making.

Effective co-ordination across government levels is particularly relevant, as many transport policy decisions are taken on a subnational level. Having a dedicated nodal agency can enhance the linking of policy makers from the different government levels. For example, in the United States, the Joint Office of Energy and Transportation co-ordinates activities between the Department of Energy and the Department of Transportation while collaborating with their respective state-level counterparts.

Avoid fossil fuel subsidies and introduce differential pricing

Holistic and co-ordinated policy making in the transport sector with the aim to decarbonise should also avoid continuing or implementing distortive incentives. This means phasing out fossil fuel subsidies, especially for transport oil, with simultaneous targeted support for vulnerable households.

For example, India successfully used a period of relatively low oil prices in 2014 and 2015 to phase out subsidies for transport oils. Introducing a carbon price could reinforce shifting the incentive basis towards low-carbon fuels and technologies in the road transport sector – again by simultaneously providing targeted support for vulnerable households. The European Union is pioneering this by introducing an Emissions Trading System (ETS) for road transport and buildings while providing targeted support through a Social Climate Fund.

Promoting public transport and demand management

Enhance a modal shift towards public transport and active mobility

A modal shift from privately owned vehicles to public transport modes such as bus and rail services – in urban and rural environments – is part and parcel to managing the demand for cars while meeting needs for safe mobility and reducing congestion. This requires the buildout of public transport systems through increased public investments in transport infrastructure and stringent inclusion in urban – and interurban – planning, as well as setting appropriate incentives for the use of public transport and ensuring a safe environment for its users.

Notable examples include creating bus rapid transit (BRT) systems with separate bus lanes on public roads. Urban centres struggle with population growth and traffic congestion, and such systems often allow customers to reach their destinations faster than with other modes of transport. This has been successfully implemented in Jakarta. Another successful example is the Curitiba BRT system in Brazil, opened in 1974, which is widely regarded as one of the first BRTs and which inspired other cities such as Bogota, Jakarta and Mexico City to develop their own BRT systems. The system in Bogota now transports almost 2 million people on an average business day, and those in Jakarta and Mexico City transport around one million people daily.

Transport by rail is another effective, though significantly more capital-intensive, mode to satisfy mobility needs. It often requires significant investment, which could be a worthwhile investment focus for blended finance (capital provision from development banks and private finance).

For example, on the back of its strong economic growth, China has constructed more than 42 000 km of high-speed railway. This has improved substantially the interconnectivity of its major cities and provinces, displacing demand for air and road travel and ensuring the affordability of mobility for large parts of the population. The Government of India is also aiming to improve its rail network, especially in cities, in response to increasing urbanisation: about 4 000 km of metro and suburban railways are already operating, with another 1 000 km under construction.

Such development of urban public transport should also be combined with encouraging and enabling active mobility such as cycling, walking or other innovative mobility measures to limit the use of private car transport for short-distance trips. Upgrading or creating the necessary infrastructure like pavements and cycle lanes can provide an incentive to safely switch the mode of transport and can be combined with additional incentives and encouragement to accelerate behaviour change.

For example, Colombia adopted a law in 2016 that provides employees with half a paid day off for every 30 times they cycle to the office. Many cities in advanced and emerging economies also used the Covid-19 pandemic as an opportunity to accelerate a modal shift to active mobility by transforming some car lanes to cycle lanes and giving more space to pedestrians on public roads. Mexico City has pursued this strategy especially actively by adding around 50 km of bike cycle lanes 2020 alone. The capital city now aims to increase the length of its cycle lanes to reach 600 km by 2024.

Box 3.1 Mobilising finance for public transport infrastructure in EMDEs

In the past two decades, financing new infrastructure for public transport in EMDEs has often involved public finance through public procurement programmes or state-owned enterprises. However, fiscal constraints in emerging economies increasingly limit such an approach, forcing a rethink on how to finance the buildout of public transport infrastructure.

Some EMDE projects have been successful in using alternative financing instruments such as grants, early-stage equity, green bonds, PPPs and joint ventures. For example, India issued a green bond in 2017 through its state-owned Indian Railway Finance Corporation to finance low-carbon transport projects, raising USD 500 million from international investors.

Development finance can also be an avenue to mobilise finance for public transport investments. The 2021 Peshawar Sustainable Bus Rapid Transit Corridor Project in Pakistan aims to construct the city's first BRT system to improve mobility and air quality while also reducing traffic congestion. It has received almost USD 500 million from the Asian Development Bank and the French Development Agency. On top of this, regional partnerships among like-minded cities can promote knowledge sharing, development of regional industries and mobilisation of investments.

For instance, the Zero Emission Bus Rapid-deployment Accelerator partnership of major Latin American cities in Brazil, Chile, Colombia and Mexico secured more than USD 1 billion in investment commitments from private investors to accelerate the deployment of zero-emission buses. Besides, it secured commitments from major manufactures such as Volvo and BYD to ramp up producing such vehicles for the region.

Another way to finance especially capital-intensive high-occupancy rail is through capturing increases in land value generated by greater connectivity and activity in areas that are connected to rail networks such as high-speed rail and metro systems. For example, Hong Kong's public operator, the Mass Transit Railway (MRT) Corporation, generates 60% of its total revenues from non-transport sources.

Decarbonise public transport

A precondition for any decarbonisation effect associated with modal shift is the swift public transport decarbonisation. This can also generate significant air pollution co-benefits. Electrification of buses – and any remaining diesel trains – is important for this, with electric buses in most selected emerging economies reaching shares of up to 55-85% of the bus stock by 2050 in the APS.

Public procurement requirements for ZEVs, subsidies for the purchase of electric buses and CO_2 standards can support this shift. A successful example is the bulk procurement programme run by India's public sector joint venture Energy Efficiency Services Ltd. It purchased more than 5 000 electric buses at a competitive price owing to the size of the order. It is now planning to tender a purchase of 50 000 buses over the next five years.

Accelerating cars and two- and three-wheelers electrification

Implement demand-side policies to accelerate market demand

Increased use and reliance on public transport in the selected emerging economies does not offset the expected growth in the use of personal vehicles. Many citizens in these countries are yet to purchase their first motorised personal vehicle. Bringing down costs will therefore be critical to achieving EV uptake at scale. Even though EV and battery costs have declined, EVs remain much more expensive in their acquisition than comparable ICE models. Major EV markets such as those of China, Germany, Japan, United Kingdom and United States have been subsidising EV purchases for years. Other selected emerging economies are also starting to introduce or expand such purchase subsidies. India extended its flagship FAME programme in 2019, thereby securing purchase incentives until 2024; and in 2021, it raised the subsidy for electric two-wheelers. Indonesia plans to begin subsidising EV purchases in 2023. In some countries, upfront incentives are also provided at the subnational level. Several countries, including China, Costa Rica, India, Indonesia and Ukraine, also reduce purchase taxes for EVs, to lower upfront costs. Subsidies can be related to income (as done in California) or limited to EVs below a certain thresholds (as done in India), to ensure they reach those that need them most. As battery prices and EV costs fall, subsidies can be gradually reduced and phased out.

China introduced a nation-wide subsidy programme in 2013. However, to lower costs, it has since introduced annual caps for eligible vehicles. Recognising the increasing cost-competitiveness of EVs, the subsidy has been phased down in the form of a base subsidy amount reduction of 10%, 20% and 30% each year from 2020 to 2022. China's subsidy scheme incentivises longer-range battery EVs over time, with the effect that the average range of battery EVs sold has increased by 50% since 2016. Despite decreasing subsidies, EV sales in China have continued to increase, profiting from strong domestic production and lower price points.

There are also policy instruments that help push demand for EVs without putting a burden on public finances. One example is the establishment of zero-emission zones – areas where only ZEVs, pedestrians and cyclists are granted unrestricted access. Most low-emission zones established or announced are in Europe, but this may change in the future.

The town of Kevadia in India plans to convert part of the town into a zero-emission zone. The Chinese cities of Beijing and Shenzhen have established low-emission zones for freight vehicles, while Foshan and Luoyang have announced plans to do so.

Governments can also establish certain privileges for EV owners, such as access to special parking areas (including preferential parking rates), access to preferential lanes (such as bus or taxi lanes) or reduced rates on toll roads. Targeting daily operational or on-duty vehicles for government officials across the country, Indonesia has mandated the use of battery BEVs and started to switch vehicles in 2022. The Government of Delhi has also proposed a fleet mandate in a draft regulation of July 2022, requiring companies running delivery and transportation businesses to electrify part of their vehicle fleet, with the required shares increasing over time.

Prioritising an early transition of fleet vehicles can also help establish a used market for EVs. This would make electric cars available at a more affordable cost for a larger portion of the population.

Implement supply-side policies to increase market availability of EVs

In addition to facilitating the availability of EVs, supply-side policies such as production incentives, standards and mandates can help increase the availability of EV models on the market. A lack of models deters consumers from purchasing EVs, even when adequate purchase incentives and charging infrastructure are in place. Supply-side policies also play a role in countries with an automotive manufacturing base, where battery and EV manufacturing can become a source of economic growth and competitiveness.

India provides supply-side incentives for manufacturing of EVs, EV components and batteries through production-linked incentives, with a budget outlay of more than USD 5.5 billion. Similarly, Thailand provides manufacturers with subsidies of up to USD 4 500 per produced EV, and USD 500 for electric motorcycles, to encourage investment and EV deployment. In addition, to combat local skilled worker shortages, the Thai government has halved the income tax rate to 17% for skilled foreign professionals working in target industries such as the next generation automotives industry until 2032.

Stringent regulatory frameworks can also push car manufacturers to pivot from ICE to EV models. Fuel economy and CO_2 emissions standards are important tools in this respect (see Chapter 2). Some jurisdictions, including California and 14 other US states as well as China, have adopted mandatory targets on EV sales.[15] California also adopted the world's first sales requirements for truck manufacturers. It furthermore aims to ban the sale of new cars powered by fossil fuels as of 2035, similar to EU targets.[16] In Asia, Singapore is set to become the first country to implement an ICE ban by 2030, and China's Hainan Province targets the exclusive sale of new energy vehicles by 2030. Indonesia has also announced that it aims to sell only electric cars and motorcycles by 2050.

Globally, about one-quarter of the car market is subject to a 100% ZEV sales ambition or an ICE ban by 2035.

Strengthen buildout of the EV charging infrastructure

Successful EV deployment requires sufficient and reliable charging infrastructure. Policy makers therefore need to ensure sufficient, reliable and easy-to-use charging infrastructure is available. The IEA Global EV Outlook 2022 finds that, globally, on average, 10 electric cars are served per public charger. This has wide regional variability, for example: 7 in China, 14 in the European Union, 18 in the United States and 32 in India.

Standardising chargers and accessibility to all plugs is essential to initiate the wide development of charging infrastructure. Regulations that open and allow new actors and business models around charging infrastructure to invest can accelerate EV uptake.

Public procurement can be an enabling step to develop charging infrastructure available for all users. As mentioned previously, India's FAME II budgets about USD 130 million for public charging infrastructure, with the objective to install 3 000 public charging stations throughout the country. The Mexican government provides a 30% tax return incentive to taxpayers who invest in a charging station that is publicly accessible.

While public charging infrastructure is critical, most charging takes place at home and at the workplace. By 2030, 90% of chargers worldwide are expected to be private chargers. To incentivise these private investments, many countries provide some form of subsidy or tax reduction. Canada is investing USD 500 million in its Zero Emissions Vehicle Infrastructure Programme to co-fund deploying charging and hydrogen stations in workplaces and multi-unit residential buildings. In addition, provisions in building codes to encourage charging facilities and the "EV-readiness" of buildings are becoming more common.

[15] Targets are set via annual "ZEV credits" that automakers need to reach as a percentage of their annual vehicle sales, with the number of credits earned per EV sold depending on the type of vehicle and attributes such as battery range.
[16] The EU Fit for 55 package includes a proposal for 100% ZEVs by 2035 through its CO_2 emissions standard, effectively banning ICE sales.

Battery swapping is an alternative to standard charging installations, and its use is increasing in emerging economies. It allows for the sale of EVs without batteries, lowering the upfront purchase cost and making the vehicles more affordable.

China is leading the battery swapping industry, with about 1 400 swapping stations already installed. Its industry aims to install 26 000 stations by 2025, fostered by automotive standardisation and subsidies specifically for battery-swap EV models. India also aims to ramp up battery swapping and published a draft battery swapping policy in 2022. Indonesia is exploring the use of use battery swapping models to accelerate the electrification of its fleet of two- and three-wheelers.

Emerging economies may face challenges to ensure electricity access and stable grid connections, to prove that EVs are a reliable form of transportation. Thus, supply reliability and grid points are major enabling factors for electrification. More mature EV markets also need to ensure a well-connected network is developed to provide EV charging access in urban and rural areas, as well as in important transport corridors.

Access to the grid, along with supporting building regulations, interoperability standards and efficient permitting, can ease infrastructure development. Collecting data on mobility patterns can help to understand charging patterns and behaviours, to optimise EV network planning and overall grid management. In addition, technologies such as vehicle to grid enable EV batteries to feed electricity back to the grid, flattening the electricity demand curve throughout the day.

Enhancing fuel economy standards

Adopt and regularly update fuel economy standards

Fuel economy standards have had a significant impact on fossil fuel use where they have been applied stringently. To be successful, those standards must be set at sufficiently rigorous levels. Fuel economy standards for cars and two- and three-wheelers should ideally be fleet-based. They are usually adopted as corporate average fuel economy (CAFE) standards, applied to a company's new vehicle sales. If set at a sufficiently stringent level, this design can push manufacturers to pivot to ZEVs and low-emissions vehicles instead of improving the fuel efficiency of vehicles with ICEs.

Next to ensuring successful implementation, fuel economy standards also need to be regularly updated and tightened. This will help to achieve greater emissions reductions in line with increasing climate ambitions and to keep pace with new technology development. Updates should be adopted well before the new target year (about 2-4 years ahead), to give sufficient time for manufacturers to plan production, which is critical for compliance.

For instance, the United States released new CAFE standards in 2022 that require a fuel efficiency increase of 8% annually for vehicle sales in 2024 and 2025 and 10% for 2026. Similarly, the European Union adopted an update in 2019, strengthening fuel economy standards for passenger vehicles by 15% in 2025 and by 37.5% in 2030 compared to 2021. The EU Fit for 55 initiative proposed to tighten the latter to a 55% reduction.

Develop appropriate and stringent test procedures

Designing a test procedure and putting in place the required infrastructure to conduct such tests is a prerequisite for designing fuel economy standards. The method used to measure fuel economy or carbon emissions strongly affects the environmental stringency. Vehicles have a higher fuel consumption under real-world driving conditions compared to in laboratory settings. Therefore, a fuel economy standard based on a test procedure that reflects real-world driving conditions would result in a higher absolute value than one adopted based on laboratory testing conditions while having the same environmental impact.

In recent decades, advanced economies have developed their own test procedures, which have since been used by emerging economies and adapted to local driving conditions. Examples include the US combined cycle, used in Brazil and Mexico, or the New European Driving Cycle, originally implemented in an adjusted form in China and India.

There has been progress in harmonising test methodologies across jurisdictions. The United Nations Working Party on Pollution and Energy adopted the Worldwide Harmonised Light Vehicle Test Procedure, designed to represent typical driving characteristics around the world. The European Union adopted a regulation in 2017 to move from the New European Driving Cycle to the Worldwide Harmonised Light Vehicle Test Procedure to better reflect real-world driving conditions. As the first major emerging economy, China has moved to standards based on the Worldwide Harmonised Light Vehicle Test Procedure for passenger cars in 2021.

Box 3.2 Fuel economy standards for two- and three-wheelers

Two- and three-wheelers play an important role in the road transport sector of emerging economies. In these countries, two-wheelers enable the surge in private, motorised mobility. In 2021, the segment accounted for nearly three-quarters of total road transport activity in Indonesia, two-thirds in India and one-fifth in China. Three-wheelers cater for mobility service demand and last-mile goods transport.

In India and Indonesia, the segment accounts for more than 40% of total gasoline consumption, despite having substantially smaller engines and a lower energy footprint than other vehicle types.

Two- and three-wheelers are set to be front-runners in road transport electrification. Electric models are already cost-competitive in most markets. Nevertheless, most models sold still rely on gasoline. In addition, there is a trend to the uptake of heavier models that are less fuel efficient (e.g., in China and India). Fuel economy standards could ensure fuel economy improvements among models powered by fossil fuels. If set as fleet-based standards, they can also help to push electric models cost-efficiently into the market.

So far, among the selected emerging economies, only China has mandated fuel consumption standards for two- and three-wheeled vehicles. The country has long-standing expertise in setting fuel economy standards. It adopted national standards for motorcycles and mopeds in 2008. Standards were revised in 2019, coming into effect in 2020. Target values cover gasoline- and diesel-powered vehicles and are set in a tiered approach based on engine size. Standards for two-wheelers range from 1.8 L/km to 6.8 L/km, and those for three-wheelers range from 1.8 L/km to 8.0 L/km.

Given the crucial role of two- and three-wheelers in their road transport sector and the limited international experience, emerging economies have a unique role to play in the design and harmonisation of innovative standards for this vehicle type. Advanced regulations to better control the fleet's fuel consumption could boost road transport transitions. Such regulations would allow those countries to share international best practices, especially with countries that are poised to experience a surge in private mobility demand in the near term.

Starting to systematically monitor the segment's fuel consumption can help to adopt such standards in the future. Viet Nam is one of a few countries that has mandated fuel consumption labelling for two-wheelers. Issued in 2018, the regulation took effect in 2020 and applies to all new, domestically manufactured or imported two-wheelers powered by fossil fuels.

In India, benefits and design options of fuel economy standards for two- and three-wheelers are being discussed. With the introduction of tighter air pollutant emissions standards (Bharat Stage VI) in 2020, there will be a requirement to upgrade engines with more modern fuel injection systems. This will open a significant opportunity for fuel efficiency improvements in gasoline-fuelled models.

Electric models could help manufacturers to meet fleet-based targets more cost-efficiently, in particular if they are granted (modest) super credits in the form of a multiplier (e.g., an electric scooter counts twice in a company's two-wheeler sales).

Design fuel economy standards for trucks

Designing efficiency regulations for trucks is more complex than for cars. Significant variations in vehicle type, size, configuration, mission profile and duty cycle create difficulties in devising test procedures and evaluating performance. Fuel economy standards for heavy-duty vehicles are therefore usually set on a per-model or per-vehicle basis and not as a corporate average. The greatest challenge is the design of standards, while enforcement and compliance on the manufacturers' side is less problematic than for cars.

In 2020, the International Council on Clean Transportation published a stepwise guide on how to approach the design of fuel economy standards for heavy-duty vehicles.

Against this backdrop, many jurisdictions in advanced and emerging economies have adopted and implemented fuel economy standards for heavy-duty vehicles, providing valuable experience for other countries.

With nearly 3 million sales in 2021, China is the world's largest national market for trucks. It has issued three stages of progressively more stringent standards, starting in 2012 with Stage 1 and, since 2019, with Stage 3. Japan established the first mandatory fuel efficiency standards for trucks in 2006, following a "top-runner" approach in which the standards are set based on the performance of the best vehicles in the market in the baseline year. The United States adopted its first phase of fuel economy standards for trucks in 2011, updated the standards in 2016, and the current standards are valid up to 2027.

Standards for heavy trucks in India were set to be implemented in a two-phase approach. However, enforcement of the Phase II standards has been put on hold, owing to strong push-back from the automotive industry. This means that Phase I standards have now been re-notified and will continue to apply.

Decarbonising road freight

Drive innovation in and deployment of zero-emission freight trucks

Road freight, especially by heavy-freight trucks, is *the* hard-to-abate subsector within road transport. Achieving significant deployment of ZEVs in road freight is a milestone in decarbonising the entire sector. This is particularly the case in the selected emerging economies where economic and population growth is expected to drive freight demand significantly higher over the coming decades. Decreasing the costs of electric and fuel cell trucks and improving their market maturity through investing public R&D funding are essential to induce large-scale deployment.

For example, through its Hydrogen Economy Roadmap, Korea aims to invest over the next two decades in developing fuel cell technology and constructing mass production systems that could put 30 000 fuel cell trucks on the country's roads by 2040. In the United States, the Department of Energy is providing USD 100 million until 2025 through its Super Truck 3 initiative to pioneer battery electric, plug-in hybrid and fuel cell trucks.

Public R&D funding intends to fund projects that are not yet market ready and to enable and complement private sector funds. In 2021, R&D investments by globally listed companies in the trucks subsector reached more than USD 16 billion, with a focus on batteries and fuel cells. Venture capital investment in clean energy start-ups focused on low-carbon mobility, energy storage and batteries has also been increasing.

Of course, public funding is not always readily available. The Netherlands is demonstrating a novel way to raise funds for innovation. In 2023, it intends to implement a national Heavy Goods Vehicle Levy. The level will depend upon the air pollutant emission class of the vehicle – ranging from EUR 0.08/km for low-emissions vehicles to EUR 0.26/km for conventional trucks. The revenues raised flow into an innovation fund that aims to finance innovative technologies for ZEVs.

Implementing zero-emission truck regulations and standards can also incentivise market demand for electric and fuel cell trucks. Binding targets such as California's Advanced Clean Trucks Regulation can provide important medium- and long-term signals to the market. Through this regulation, the state of California requires at least 30% of heavy-freight truck sales to be from ZEVs in certain market segments by 2030 and as much as 75% by 2035. In doing so, the state sets these targets by applicable vehicle categories and zero-emission powertrains while also providing interim milestones.

Such public and private sector R&D investments, as well as market regulations, can be combined with domestic, regional or global partnership programmes that create an ecosystem of regulators, manufacturers and research organisations to accelerate innovation in the trucks subsector.

For example, the US 21st Century Truck Partnership aims to encourage the development of technologies that are more energy efficient, and which have lower emissions by promoting collaborative R&D among government and industry partners. The Global Commercial Vehicle Drive to Zero programme seeks to increase ambition by setting targets on the sale of zero-emission medium- and heavy-duty vehicles. Its signatories commit to 100% zero-emission new truck and bus sales by 2040.

Encourage modal shift and improve logistics

As Chapter 2 illustrated, even in an APS pathway, electric and fuel cell trucks are expected to become economically cost-effective abatement options in the coming decades. This is despite the increasing public funding in such a scenario. Modal shift of freight transport from roads to lower-carbon modes such as railways and inland waterways can therefore help to achieve a peak and eventual decrease in truck emissions. This is especially so until electric and fuel cell trucks become economically more affordable in the selected emerging economies.

With the development of targeted policy interventions to incentivise modal shift of freight transport, public policy can accelerate such a shift and help manage the environmental impact of the expected increase in freight demand in the selected emerging economies. Such interventions can include stringent fuel economy standards and pricing instruments such as fuel excise taxes and carbon pricing.

The European Union announced in December 2022 a provisional agreement to create an Emissions Trading System for road transport. This should decrease the cost-competitiveness of road transport to the favour of rail and waterway freight transport, while also incentivising development of ZEVs. To soften the price impact on vulnerable households and enterprises, the price level will be maintained below EUR 45/t CO_2, and a Social Climate Fund will offer additional support for temporary direct income support and investments in ZEVs.

Incentivising the modal shift of road freight transport will have to be accompanied by investments in rail and shipping infrastructure should the existing infrastructure not be suited to a significant increase in freight activity.

Improving the flow and logistics of road freight transport can be another lever to optimise road freight transport and mitigate some of its CO_2 emissions. Through modern technology such as Global Positioning System tracking, road agencies and freight carriers can reduce road congestion, guide road freight flows and improve interaction with freight hubs such as ports as well as other modes of transport such as ships.

In Brazil, the PortoLog system has been collecting freight movement data to improve port logistics through optimising the arrival of ships and cargo at terminals with programming uncongested access of trucks to the port, thus minimising waiting times for ships and trucks. This is supported by the Canal Verde programme, which implemented electronic surveillance of crucial highways to monitor and improve the flow of trucks.

Boosting the uptake of sustainable biofuels

Implement policies to support biofuel uptake

While the role of biofuels remains important in the medium term, the overarching target is the large-scale deployment of ZEVs. Policies such as the EU sales ban of ICE vehicles by 2035 and several other countries' pledges to introduce similar targets will affect and question the role of biofuels in road transport in the longer term. This will also depend on existing developments and investments in biofuels within jurisdictions.

Most of the selected emerging economies have adopted a form of blending obligation for bioethanol and biodiesel that increases in the near future. While non-binding blending targets (e.g., as part of policy road maps) can have a positive effect on biofuel uptake, blending mandates remain an important policy instrument to accelerate biofuel use and demand by imposing legally binding standards.

The Brazilian National Biofuels Strategy (RenovaBio), adopted in 2017, sets quantifiable carbon intensity targets on transportation fuels (a reduction for biodiesel from 24.2 g CO_2/MJ in 2019 to 21.1 g CO_2/MJ by 2032). RenovaBio rewards biofuels with low-carbon intensity[17] by creating a framework for tracking and compliance with carbon emissions targets, as well as certificates reflecting energy efficiency and carbon intensity of biofuels.

Financial incentives represent an additional instrument to foster demand. Indonesia subsidises domestic biodiesel consumption to support its blending mandates, aiming to offset the price difference between biodiesel and conventional diesel. India exempts biofuels from its fuel excise tax.

Stated incentives are particularly effective when integrated with policies that enable consumption and technological innovation, such as in the form of an uptake of flexible-fuel vehicles in Brazil. These vehicles are optimised to run on any mix of bioethanol and make up most of the registered cars in Brazil, representing the world's largest flexible-fuel fleet.

Promote innovative and sustainable biofuels

For the future application of biofuels in a low- and zero-emission economy, considering life-cycle emissions and sustainability criteria of the fuel is crucial. Generally, feedstock such as sugar cane does not directly compete with food production and performs rather well from a life-cycle GHG emissions perspective. However, the use of bio-oils, particularly palm oil, can be more controversial. In terms of feedstock supply shortages and increasing prices for agricultural stock,

[17] Brazil ranks the carbon intensity of biofuels based on life-cycle emissions of the different input resources.

advanced biofuels – based on non-food crops and agricultural residues – present an attractive alternative and should be promoted.

Government programmes and industry innovation will need to improve supply chains, seek out new supplies and develop new production techniques . Brazil is researching innovative non-food materials for biofuels production, also known as second-generation or advanced biofuels.

Recommendations for India and Indonesia

India

Develop a national transport transition strategy and establish a co-ordination mechanism for policy implementation across jurisdictional levels

India faces the challenge of boosting its transition to a low-carbon road transport sector, while meeting the surge in private mobility demand and the increase in freight activity linked to a growing, urbanising and rapidly developing population.

However, India does not have an overarching decarbonisation strategy for its transport sector; its last national-level transport plan dates to 2010. Reviving such long-term and national-level planning for the transport sector would be important to providing a clear vision for the sector and its stakeholders. This could be done as a separate national planning document or by developing sectoral pathways and targets for its NDC.

India's autonomous states also play an important role in country's road transport transitions. Therefore, effective co-ordination mechanisms among national, state and even city levels will be required to turn national-level planning into reality.

India could particularly benefit by exchanging best practices across states. One way to institutionalise this and to help with co-ordination across jurisdictional levels would be to consider creating a nodal agency to lead and aid policy making related to road transport. State- and city-level governments will be crucial actors in pushing the development of public transport infrastructure that can mitigate some of the increasing demand for personal vehicles and, hence, slow energy demand growth.

Renew the focus on truck electrification, enhance regulatory certainty and improve access to financing by leveraging public funds

Promoting vehicle electrification is an important lever for India's road transport transitions. On the demand side, the FAME scheme reduces the upfront purchase price of EVs to stimulate early adoption and market creation. On the supply side, two production-linked incentive schemes provide funding to boost India's EV manufacturing industry. Targets and subsidy packages have also been introduced to promote charging infrastructure development. In the future, India could focus on supporting its truck fleet electrification, for example, by setting up bulk procurement programmes, like the one for electric buses.

India will need to mobilise substantial investment to achieve large-scale transport electrification. An annual spend of over USD 16 billion in EVs will be needed in 2026-30 in the APS, and a similar amount will be required for private chargers. This compares to an annual spend of USD 0.2 billion in EVs and private chargers in 2016-21. Current policies are on track to achieve just over half of the investment needs of the APS.

EV financing continues to face challenges mainly related to lack of regulatory certainty, perception of high risk and lack of risk mitigation mechanisms, and limited availability of targeted financing instruments. In addition to improving regulatory certainty and continuing existing policy support, India could improve access to financing and help address the upfront cost barrier. This could be done by including EVs in priority sector lending, providing credit guarantees or utilisation guarantees, and lowering interest rates for targeted vehicle types.

Enhancing the sustainable finance framework and technical capacities in the banking and financial sector on clean energy projects is also important. It would support a broader set of low-carbon solutions and enable the sector's transition in general.

Broaden, regularly enhance and strictly enforce fuel economy standards

India has implemented fleet average fuel economy standards – known as CAFE standards – for cars. Manufacturers have overachieved these, and hence they have had little effect in pushing EVs into the market.

Beyond the already implemented tightening of the standards in 2022, design improvements in the passenger vehicle segment can help to drive the uptake of EVs. These could include: (i) regularly updating the standards for cars to increase their stringency, (ii) setting a financial penalty of sufficient magnitude in case of non-compliance and (iii) implementing fuel economy standards for two-wheelers.

India's recently adopted 2022 Energy Conservation (Amendment) Bill is, for the first time, stipulating financial penalties for non-compliance with fuel economy standards.

In addition to the electrification of India's diesel-reliant truck fleet, continuous improvement of the truck fleet's fuel economy is critical for its decarbonisation. Enforcing adopted fuel economy standards for the heavy-duty vehicle segment is essential to realise this. India has developed fuel economy regulations for freight trucks as per-vehicle model standards. However, enforcement has been temporarily halted due to strong push-back from the industry.

Fuel economy standards will be an important driver to ensure annual investment in vehicle efficiency doubles to USD 6 billion in 2026-30 under current policies – compared to 2021 – and additionally rises to almost USD 16 billion as required under the APS.

Combined with fuel economy standards, developing and adopting advanced biofuels through the expansion of compatible vehicles, reinforced blending targets and appropriate fiscal policies could, in the short term, help India slow the emissions growth in its road transport sector while also mitigating oil import dependency. Importantly, this should be combined with sustainability criteria that assess the GHG emissions performance of these advanced fuels and support the use of, for example, domestic waste and residues in the production of such biofuels.

Indonesia

Elaborate the national transport transition strategy and implement fuel economy standards

To decarbonise road transport emissions, Indonesia will need to significantly enhance its road transport policy package and balance decarbonisation with meeting surging demand for mobility and freight transport. This should involve elaborating a long-term transport transition strategy – building on the transport-related elements developed for the 2021 Long-Term Low-Emissions Development Strategy.

Energy efficiency will also be an important element in this endeavour. No fuel economy standards exist to incentivise car manufacturers and importers to sell more efficient vehicles. This results in a relatively high level of fuel consumption (8.8 litres of gasoline equivalent (Lge) per 100 km on average for passenger cars), significantly higher than in India (6.5 Lge/100 km) and the world average (6.7 Lge/100 km). Implementing fuel economy standards before the end of this decade could drive the average fuel economy for new cars down to 5.9 Lge/100 km by 2030, compared to 6.6 Lge/100 km in the STEPS.

Standards could also have a significant impact on trucks. In the APS, the average fuel economy of heavy trucks could decrease to 29 Lge/100 km by 2030 – a drop of more than 17% compared to 2021. In addition, the buildout of public transport infrastructure especially in urban centres is crucial to mitigate fuel consumption growth while also tackling traffic congestion.

Accelerate electrification of the fleet and incentivise development of the domestic EV value chain

Another lever for Indonesia's vehicle fleet decarbonisation is its electrification. Indonesia is one of the few emerging economies to have announced a 100% sales share target for electric two- and three-wheelers, as well as cars, by 2040 and 2050, respectively.

To reach these targets, Indonesia will need to scale up its EV production and create the appropriate market demand. This can be done by providing market incentives to improve the competitiveness of especially cars and trucks, including subsidies as developed in other selected emerging economies like China and India. The deployment of charging infrastructure will also be an important enabler for its fleet electrification.

The development of an EV supply chain is another crucial factor in this and for the competitiveness of Indonesia's economy. The country already occupies leading positions in certain elements of this future supply chain, for example in the processing of nickel. Local content regulations, as recently adopted (80% for electric two-/three-wheelers and EVs by 2026 and 2030, respectively), can provide additional support for creating a local EV production supply chain. However, they should be carefully designed to avoid trade conflicts and to avoid undermining the long-term competitiveness of a local EV industry.

Consider phasing out subsidies for transport while protecting vulnerable households

A complete phase-out of fossil fuel subsidies should also be considered in the transport sector. This would create a level playing field for EVs and fuel cell vehicles and provide the right incentives for investments and consumption.

In 2021, Indonesia spent USD 13 billion to subsidise transport oil, mostly on value-added tax exemptions for gasoline. Progressively removing these subsidies would enable the government to finance incentives for EVs and fuel cell vehicles, as well as for clean energy manufacturing.

In the long term, this could be complemented by introducing, for example, a carbon price for the road transport sector coupled with appropriate support measures for vulnerable households. That would boost the cost-competitiveness of EVs and fuel cell vehicles, which will require additional support to become cost-effective, even in the APS. It could also reduce fuel demand in Indonesia and reduce oil import dependency by extension, while generating revenues for the government.

Leverage public funds in a clear and transparent manner to accelerate private finance investments

Transitions will require considerable investment in vehicle efficiency and EVs in Indonesia, which need to grow eightfold to over USD 4 billion annually in 2026-30 in the APS compared to in 2016-21. Infrastructure investment is also needed to enable electrification, as is investment in public transport and active mobility alternatives such as walking and cycling.

Indonesia needs to send a clear signal to private investors, with transparent policy and regulatory frameworks, and use public funding strategically to leverage private investment. This could include using public procurement to scale up market demand for new technologies and providing loan guarantees to de-risk projects in priority areas.

Indonesia could also enhance sustainability criteria and integrate transport transitions priorities in its PPP framework to leverage the system to accelerate development of charging infrastructure and public transport solutions. Improving access to affordable and longer-term financing would be important to accelerating investment in clean energy projects. It could also support consumers to overcome the barrier of higher upfront costs of more efficient EVs, such as through purchase subsidies, which can be financed by repurposing fossil fuel subsidies or introducing EV loan programmes.

Annex

Abbreviations and acronyms

APS	Announced Pledges Scenario
BRT	bus rapid transit
CAFE	corporate average fuel economy
EMDE	emerging market and developing economy
EU	European Union
EV	electric vehicle
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
GDP	gross domestic product
GHG	greenhouse gas
ICE	internal combustion engine
IEA	International Energy Agency
MACC	marginal abatement cost curve
NDC	nationally determined contribution
NO_x	nitrogen oxides
PM	particulate matter
PPP	public-private partnership
R&D	research and development
STEPS	Stated Policies Scenario
SUV	sports utility vehicle
US	United States
WEO	World Energy Outlook
ZEV	zero-emission vehicle

Units

CO_2	carbon dioxide
EUR	Euro
g CO_2/km	grammes of carbon dioxide per kilometre
g CO_2/kWh	grammes of carbon dioxide per kilowatt hour
g CO_2/MJ	grammes of carbon dioxide per megajoule
Gt CO_2	gigatonne of carbon dioxide
km	kilometre
Lge	litres of gasoline equivalent
Lge/100 km	litres of gasoline equivalent per 100 kilometres
L/km	litres per kilometre
Mt CO_2	million tonnes of carbon dioxide
Mt CO_2-eq	million tonnes of carbon dioxide equivalent
Mt NO_x	million tonnes of nitrogen oxides
Mtoe	million tonnes of oil equivalent

EJ	Exajoule
t	tonne
t CO_2	tonne of carbon dioxide
USD	United States dollar
µg/m^3	microgrammes per cubic metre

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